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NEBULAE WITH DARK LANES.

In Plates XI and XII we have attempted to reproduce 24 very interesting photographs of spiral nebulæ seen edgewise, or nearly edgewise. These are from Plate III of the Lick Observatory Publications, Volume XIII, and the original photographs were taken by Heber D. Curtis with the Crossley Reflector. A very striking feature of these nebulae is the dark streak, or lane which crosses each,—centrally through the first three and below the center in the others. In Figure 3, Plate XI, the appearance curiously resembles that of the two carbons of an arc light.

These nebulae are of very different apparent sizes and brightness, and stand at all angles with the north and south direction in the sky. Dr. Curtis has given them different lengths of exposure, different enlargements, and arranged them with their major axes parallel to each other for the sake of easy comparison. Where the dark streak is not central it has been placed below the center, for the same reason and because in all probability the part of the nebula containing the dark streak is the part nearer to us.

What are these dark streaks? Looking at this array of photographs one can hardly accept the explanation that they are empty space,—holes or lanes through the substance which gives the nebulous light. One is almost forced to say that they are due to opaque matter which intervenes between us and the luminous matter beyond. In Figure 6, which shows the finest example of dark streak, the impression given is that of a dark ring of matter encircling the nebula in nearly the same plane with the bright whorls. The details of spiral structure in the latter, which are very indistinct in the original photograph, have been lost in the reproduction.

In several of the photographs both the dark and light whorls of matter are fragmentary in structure. In Figure 23 the spiral character is quite evident, but the dark streak seems certainly not a complete ring or spiral whorl and is more like a long overlying cloud, perhaps somewhat above the general plane of the luminous spirals.

Dr. Curtis has given, in Plates III, IV, V, and VI, a series of 78 photographs of spiral nebulæ,arranged in an approximately progressive order of inclination to the line of sight. Those whose planes are nearly perpendicular to the line of sight do not show the effect of exterior

whorls of dark matter, but reveal in many instances dark lanes between the spiral arms and in some instances these also seem to encroach upon the contiguous bright areas.

The letters N.G.C. and the second number opposite each picture refer to the designation of the nebulæ in Dreyer's New General Catalogue of Nebulae.

IS THE EARTH EXPANDING OR CONTRACTING?

Earth Physics and Considerations on Geological Phenomena.

By HIRAM W. HIXON.

The cause of elevation, folding, faulting and other changes in the earth's crust which raised what was once covered by the sea, in a former geological period to the land we live on, has been variously stated, but further examination has shown that the old hypotheses will not explain the observed facts.

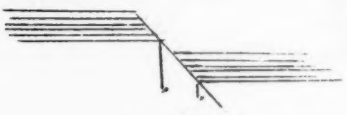


FIG. 1.
Normal Fault, or Stretch Fault.

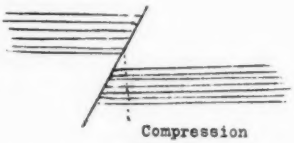


FIG. 2.
Compression or Reversed Fault.

All faults are either normal or reversed and of these two types ninety per cent according to Chamberlain are normal.

Normal faults show stretching or extension; see sketch 1.

The normal fault is called normal because it is the dominant type, and it is impossible to produce this type by contraction of the hot interior of the earth acting on the cold crust for slumping down must be preceded by elevation.

It is not generally known what the cause of causes is, but if the argument which follows is correct then it must be local and regional reduction of density which causes elevation and local and regional increase of density which causes subsidence. Unloading or erosion accentuates elevation, and loading by deposition of sediments accentuates depression, but neither is the ultimate cause of either elevation or depression. The Grand Canyon area was a region of depression for a long geological period, and then it became a region of elevation. The unconformities show (Fig. 3) that these conditions have been reversed three or more times on a gigantic scale, and many times on a minor scale. In Dutton's "Monograph on the Tertiary History of the Grand

Canyon" his analysis of the process by which the Canyon was cut is that the river was there first, and the plateau rose in the path of the river. This is obviously true, because rivers do not run over plateaus 8,000 feet high and cut canyons through them, when there are regions of less elevation in which they can flow. We are therefore confronted with the necessity of finding a competent cause for the elevation from below sea level to an altitude of 18,000 feet above sea level, of a dome in the earth's crust 150 miles in diameter. There have been removed from the Grand Canyon area, according to Dutton, 10,000 feet of strata of various geological ages overlying the carboniferous, which is exposed in the rim of the Canyon at present at an altitude of 8,000 feet in the north wall. Loading furthered depression of the sedimentary series, but when deposition ceased, the surface was still at or below sea level, and erosion could therefore not be the cause of elevation The elevation is greatest where erosion has gone deepest, which is in the Canyon itself. The proof of this is that all the surface drainage is away from the Canyon rim and one is obliged to go up hill to the Canyon. This is due to the fact that the removal of the immense weight of material in the cutting of the Canyon has caused an increased uplift over the area near the Canyon and reversed the dip of the strata as in an anticlinal.

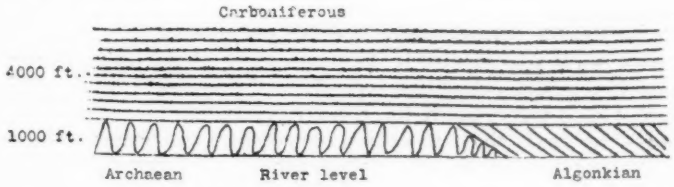


FIG. 3.

Diagrammatic elevation of the north wall of the Grand Canyon opposite Bright Angel Trail; showing the two great unconformities, each of which marks a period of erosion of a land surface subsequently submerged and deeply covered with sediments. The region was later elevated and a dome or mountain range eroded off, and this repeated three times.

The top of the series is called the carboniferous, the inclined series the Algonkian, and the bottom is folded and contorted Gneiss, which shows distinct bedding planes and was originally of sedimentary origin and necessarily the product of erosion of an unknown continent. The Cayon in the Gneiss is called "Granite Gorge."

But the elevation has been great in regions remote from the Canyon, so that the cutting of the Canyon cannot be the cause of more than local adjustment to an isostatic balance. This isostatic balance is world wide as well as local, and the continents and islands which stand above the ocean bottom do so simply because the sub-crustal material beneath them is less dense than beneath the more depressed parts of the earth.

The rocks composing the stratified series in these elevated regions testify to the fact that they were deposited below sea level, and we are, as in the case of the Grand Canyon area, obliged to explain how the immense weight of the continental masses have been lifted to their present positions.

The contraction hypothesis is incompetent to explain these changes of altitude because of lack of strength in the crust, as shown by Woodward and other investigators. Calculations were made on the strength of earth domes, taking into consideration strength of materials and weight, and it was found that when considered as a dome of the radius of the earth, twenty-five miles thick, and of material equal to the crushing strength of granite, that such domes would not support one five-hundredth part of their own weight if they were one hundred miles in diameter. Obviously, if domes of such small diameter are not self-supporting, then domes of continental size cannot be, and the crust must at all times be supported by the material below it.

If it is in isostatic balance at all times, and varies in altitude from one geological age to another, then the only solution to the problem is that a part of the subcrustal material varies in density between these dates.

The cause of the variation in density is now the chief concern, and it is necessary to depart a considerable distance both in time and subject to explain that.

To begin with, it is necessary to define several things:

1st—Critical temperature is the temperature above which matter is always in a gaseous condition regardless of pressure.

2nd—Gas is matter above its critical temperature.

3rd—The sun is above its critical temperature as a whole and therefore gaseous throughout, and in the central portion gravitational compression makes gases of a greater density than the solids that may form out of them when cold.

4th—Gas of greater density than solids is still gas, and subject to the laws governing diffusion, and will support or float a crust of solids and may be called solid gas.

5th—According to Graham's law of the diffusion of gases in a mixed body of gases, each gas occupies the whole space as if the other gases were absent.

6th—In a sun or planet in an incandescent condition it must follow, if these laws be true, that each gas will diffuse clear through the whole planet irrespective of density, and occupy the space where gravitational compression has made the density greater than the solids which will form out of them at the surface when cold.

7th—Rigidity is a property of matter that resists deformation to sudden movement and is relative to that movement.

For example, the earth as a whole is said to be as rigid to the tidal movement as a sphere of steel, but it yields to centrifugal force, and

is of greater equatorial than polar diameter. It also yields to reduction of density as shown, and the isostatic balance is preserved by yielding to small forces long continued, like loading and erosion.

Rigidity is a property of cold matter, as we are used to it, that is lost when the temperature is much increased whether fluidity is reached or not, as for example: A bar of steel heated in a forge is rigid on the cold end and soft on the hot end.

Therefore, an increase of temperature of 1 degree Centigrade for each 100 feet of depth will cause a plastic condition or a zone of rock flowage long before the melting temperature is reached in a solid globe.

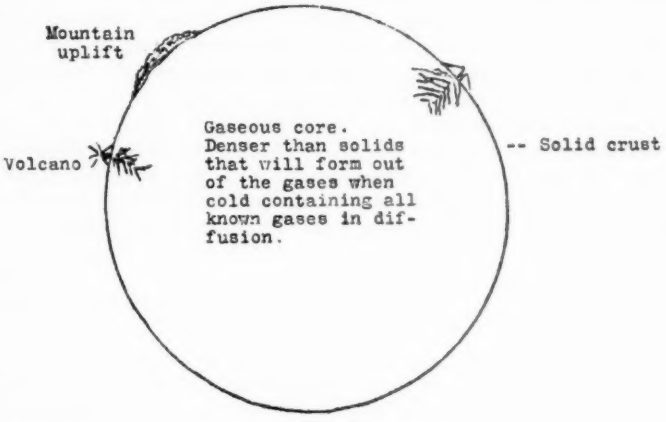

Mountain uplift
Volcano
Gaseous core. Denser than solids that will form out of the gases when cold containing all known gases in diffusion.
-- Solid crust

FIG. 4.

Diagrammatic section of the earth to illustrate the theory of a gaseous core denser than the solids which form out of it: 7700 miles in diameter, with a solid crust about 150 miles thick. The core contains some of each of the gases which were originally in the gaseous planet sun, and are held there by the power of diffusion until liberated by the cooling of some of the elements below their critical temperatures. These elements become solids because the gravitational compression raises the fusion point to the critical temperature. The average density of the earth is about 5.6, water being 1; so that at the center the density must reach 10 or more. At the surface the cold material has an average density of 2.7, and pressure increases at about 3 tons per square inch per mile of depth. The rate of increase, increases with the depth and at the center of the earth is about 25000 tons per square inch. The crust is much thinner in regions of volcanic activity and the increases of temperature with depth is much more rapid than in regions covered with thick beds of sedimentary rocks. The average, so far as known, is about 1° C. for 100 feet of depth, or about 50° C. per mile of depth, which would give 5000° C. at 100 miles if the increase is uniform, which it probably is not. If 5000° C. is reached at 100 or 150 miles of depth that would be above any temperature that can be produced in an electric furnace, and as we know, high enough to boil silica and volatilize all known substances.

The most recent information regarding increase of temperature with depth has been obtained from a well drilled to a depth of 7,580 feet at Valley Falls, W. Va. The temperature near the top of the hole was 52° and at the bottom 170° F. This increase is at the rate of 1.56° F. or .865° C. per 100 feet, and is also the greatest depth to which a bore hole has been drilled.

As a result of rock flowage without melting, all cavities are closed at a mile or less of depth, and in deep mines it has been found that surface waters do not go much below two thousand feet, and below that the workings are dry. Notwithstanding this fact, lavas which come from great depth are porous and full of gas and steam when they issue from the craters, and it is now known that gases, a considerable portion of which is steam, 75 per cent by analysis in the report of the observatory on Kilauea for July, are the sole cause of the elevation of the lava in the craters and the craters themselves, and all the other phenomena known as volcanic action, and as I shall show, also of geysers and hot springs.

Chamberlain's postulate of a cold earth developed from planetesimals is not in accord with the observed fact that the moon, with only one-eighty-first part of the mass of the earth was formerly molten, as shown by the crater rings which are visible on its surface.

Assuming an incandescent condition for the earth before it had a crust, we have the origin of the gaseous core or solid gas, with rigidity corresponding to compression and containing some of each of the gases which were in the original gaseous planet.

The gases of low critical temperature will continue to be held in the gaseous core by the power of diffusion so long as the temperature is above the critical point for all, and as the mass on the outer surface of the gaseous core loses heat and falls below the critical temperature of *some* of the elements, they pass from the gaseous to the solid condition because the gravitational compression has raised the fusing point to that of the critical temperature, eliminating the fluid condition. The gases of low critical temperature such as Nitrogen, Hydrogen, Co, Co_2, So_2, etc. can no longer remain in diffusion with solids, and they work their way up through the zone of solid flowage to the bottom of the zone of fracture by some process similar to osmosis; by which they constitute an integral part of a non-porous medium with additions from below and relief from above. They act as carriers of heat from the zone of critical temperature to the focus of volcanic fusion, and when sufficient gases and heat have accumulated break through to the surface and cause the various physical phenomena known under the head of volcanic action (Fig.4).

They rise uniformly from the zone of critical temperature or solid gas, but owing to long established channels do not reach the surface except in localities of volcanic activity. Their first effect is to reduce the density of the rock matter, which they fuse by their contained

heat, and this reduction of density causes elevation at the surface of the solid crust in the same manner that the leavening gases cause the elevation of the surface of a loaf of bread: Example, the Black Hills, S. D. When sufficiently accumulated, the elastic pressure of the gases pulls the zone of fracture apart, and the gases rush into the fracture carrying along the fused rock matter as a dyke or sill, which may or may not reach the surface and result in volcanic action. Dissected craters are shown to be located above dykes, as witness the one on the Canyon rim at Vulcan's Throne, Grand Canyon (Dutton). Lavas are local fusions of rock by volcanic gases and vary widely in composition from the same crater at different eruptions.

The matter of reduced density below the zone of fracture tends to seek a higher level and displace matter of greater density. This results in the phenomena known as stoping or thinning of the zone of fracture, and is characteristic of volcanic regions, and is the means by which craters are bored through horizontal bedded strata not otherwise disturbed, as for example, the diamond pipes in South Africa and Devil's Tower in South Dakota. This creep of rock matter saturated with gas from regions of great depth is influenced by the heat gradient or isogeotherms; and in a region where deep ocean areas border on the land, and high mountains are near the sea, it results

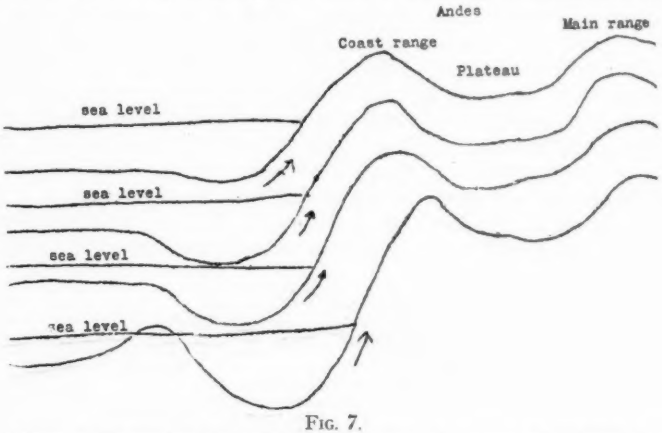


FIG. 7.

Diagram illustrating the result of the creep of matter of reduced density beneath the zone of fracture on steep slopes from deep sea troughs toward high mountains. The sea trough is deepened while the sea beaches and mountains are elevated periodically at time of sudden movements and earthquake.

The submarine ridge to the left of the trough will in time become a third range of mountains and the elevated trough will be filled with the wastage of the mountains in the same manner as the plateau surrounding Lake Titicaca has been filled. The festoon of parallel ranges of mountains shown on maps are thought to have been formed in this manner.

in sudden upward movements which carry the crust blocks in a sudden lurch, just like a land slide only reversed in direction. In this way the ocean becomes deeper and the land higher (Fig. 7). The crust blocks moved in this manner may contain many thousand cubic miles of matter, and the momentum of such a mass when suddenly stopped is enough to shake the whole earth, and the result is called a tectonic earthquake. The volcanic type of earthquake has the same cause of causes but is more local in character. Being at a shallower depth, its effects are not felt over so great an area and may result from the intrusion of steam accompanying the advance of a dyke or sill into a fault plane which was opened by the elastic pressure of the steam, and the shock may be partly due to the sudden condensation of the steam when in contact with the cold walls.

Such a fault plane opened and closed several times with accompanying noises of rushing steam and heaving of the ground, will explain most earthquakes. The condensed steam escapes as water along with the gases through craterlets, many of which were found at Charleston and New Madrid.

The accumulation of matter of reduced density beneath a mountain range which has been shown to exist by the use of a vibrating pendulum according to the Coast and Geodetic Survey, is to be accounted for in the manner just described. And as the accumulation takes place from the opposite sides of the range of mountains, and the crust blocks are carried in two opposite directions, folding and overthrust occur as a result without the contraction of the planet as a whole, the stretch of normal faults compensating the folding and reversed faults (Figs. 1, 2 and 5). It has been estimated that all the contraction produced by the loss of heat in a hundred million year period would not result in decreasing the circumference of a great circle of the earth more than seven miles. It has also been estimated that if all the folding and overthrust were ironed out of the mountain

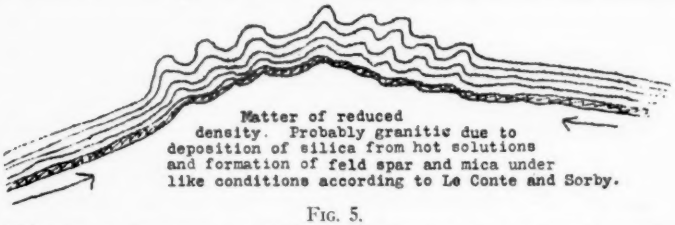
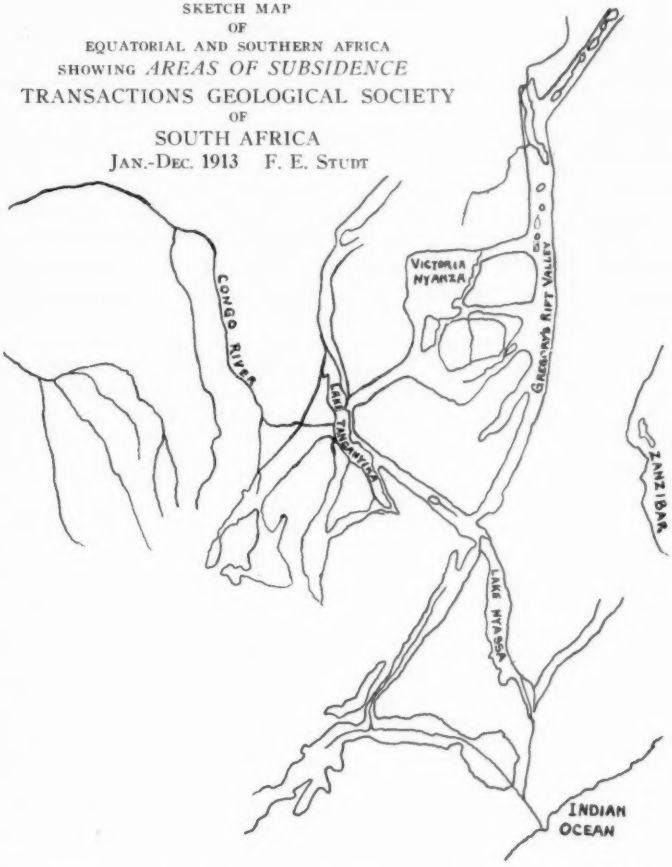

Matter of reduced
density. Probably granitic due to
deposition of silica from hot solutions
and formation of feld spar and mica under
like conditions according to Le Conte and Sorby.

FIG. 5.

Diagram to illustrate the folding and elevation of a mountain range by the creep of matter of reduced density beneath the cold crust toward the axis of elevation or center of a dome. The bottom strata are much more folded and crumpled than the top, because of their higher temperature and greater friction. The crust is carried in two opposite directions, and folding and overthrust in the mountains is compensated for on the sides where the crust is stretched and normal faulted.

ranges in a similar great circle, that it would amount to one hundred and twenty to one hundred and fifty miles (Chamberlain). Here is a discrepancy that calls for just the explanation offered; that folding is due to the carrying of the crust against itself from the opposite sides of the axis of accumulation (Fig. 5).



Contraction is inadequate to account for the observed folding and if due to folding would be continuous, whereas mountain building is epochal. According to the explanation given, there may not only be *no* contraction, but actual expansion of the earth as a whole. The reason for this is plain. If the earth has a gaseous core *denser* than the solids that will form out of its gases, and this core by loss of heat

is gradually becoming solid, then it will occupy more space (Fig. 6), and the earth as a whole will be expanding instead of contracting, which will mean a slowing down of its speed of rotation and a lengthening day. The reason for this is that the momentum of rotation is fixed and if the diameter increases by expansion the speed of rotation must decrease. The question is at once suggested, "Have we any evidence that it is expanding?" And the answer is supplied by the millions of normal faults, all of which indicate a stretching of the crust (Fig. 1), and also by the great rift valley which extends from south of the Equator in East Africa to the valley of the Jordan in Palestine.

By analogy, the so-called Canals of Mars may be the result of the expansion of a once gaseous core on a rigid crust (Fig. 6), with the consequent inflow of most of the water on the surface and the growth of vegetation adjacent to the water. Also the slower revolution of the planet would explain why the inner satellite of Mars revolves in less time than Mars itself does, because the speed of rotation of the satellite would not be influenced by the expansion of the planet.

FIG. 6.

Diagram illustrating the effect of the expanding of a gaseous core, denser than the solids that would form out of it, on a cold crust. The water would be withdrawn from the surface, and the speed of rotation reduced. The momentum of rotation must remain constant, and if the diameter is increased, the period of rotation must increase also. This is the probable reason why the inner satellite of Mars revolves around Mars in less time than Mars revolves on its axis. The cracks in the crust would explain the so-called Canals of Mars, as well as the great rift valley of the earth in East Africa, and the Rill Cracks on the moon.

—After Le Conte.

The block faulting in the Great Basin in Utah and Nevada is another example of a region showing expansion.

The point of greatest practical interest to students of this subject is the thought, that if all the land areas are held above the level of the

ocean by reduction of density, then we, and all air-breathing animals owe our development and existence to that one fact, for without that force all the lithosphere would have remained at a uniform altitude, and the waters of the ocean would cover the entire surface of the planet, and nothing living could develop, except it swam in the limitless sea.

Whether we have elevation or subsidence in a region is a relative matter, and depends on whether accumulation of the leavening gases in the regions below the zone of fracture is more or less rapid than their escape to the surface through volcanic vents, hot springs, etc., or the movement of matter of reduced density from beneath one region to another. The solution of the geyser and hot spring problem is simply a calculation of the heat units that would have to be derived from the contact of cold surface water with hot rocks. In the Yellowstone Park there are reported to be about 4,000 hot springs, geysers and steam vents. Some of these discharge steadily a large amount of boiling water, while many are relatively small. All told, 20,000 gallons per minute does not appear to cover the quantity, and at 8 pounds per gallon, this would be 160,000 pounds per minute, or 80 tons. Water has a specific heat of 1 and ordinary lava of 0.20, so that it would require the cooling of 5 times the tonnage of lava through the same range of temperature as the water, say 150°, from 62° F. to 212° F., or the same tonnage of lava cooled through five times the range of temperature, or 750° to supply the heat units.

There are 1440 minutes in a day and 525,600 minutes in a year, which multiplied by 80 tons gives 42,048,000 tons of lava cooled through 750° F. to supply the heat for a single year. At 2.5 tons per cubic yard this represents about 16,800,000 cubic yards, or put another way, a cubic mile of lava would supply heat for 324 years, or 308 cubic miles would be required to supply heat for one hundred thousand years.

The geysers and hot springs are in deeply eroded country, young in a geological sense. Some of the geyser cones show signs of glaciation, so that they are evidently many times one hundred thousand years old. It is impossible that surface waters can come in contact with, or extract the heat from, such a huge quantity of lava by conduction, because the conductivity of lava is so low that if the outer surface be cold, though the interior be hot, relatively no heat would pass to the water.

The travertine deposited from solution at the surface as a cone and all the way up the pipe completely isolates the pipe from surface waters as the casing of an oil well does, and therefore condensed steam from the gaseous core forming magmatic water is alone discharged.

The escape of all known gases from volcanic vents and from the fluid lava while cooling has been observed. This is in accord with the known facts of what should be the case according to the law of diffu-

sion of gases applied to a gaseous planet. Hydrocarbon gases have the same reason for being in the gaseous interior as the other gases, and their accumulation and condensation to oil beneath impervious sedimentary deposits would explain the origin of petroleum.

The hydrothermal solutions resulting from the condensation of steam from the interior would leach out the metals from the hot rocks in the path of their ascent, and deposit them in faults and fractures near the surface because of the effect of relief of pressure and falling temperature on the solvent power of the solution, thus making ore deposits.

Finally, the question of probability of the correctness of any hypothesis increases about as the sum of the squares of the number of observed facts that it will explain or agree with. If it will explain all of the known facts which other hypotheses explain and also those which they fail to explain it has an infinitely greater probability of being correct.

The foregoing hypothesis explains all* known geological phenomena except the rigidity of the earth to tidal distortion and that is assumed to be explained by gravitational compression of the gaseous core which produces rigidity as well as density greater than the solids which may form out of it. Even the hypothesis that the earth is solid is open to the same criticism because the high temperature would destroy the rigidity of a solid core.

SOME PROBLEMS IN SIDEREAL ASTRONOMY.

By HENRY NORRIS RUSSELL.

(*Continued from page* 224.)

6. Beyond the limit of direct measures of parallax, our main reliance must be placed on *proper motions*, which are of fundamental importance in the study of the galactic system.

The brighter stars have already been cared for by Boss, and those down to magnitude 7.5 are under discussion. The fainter stars can best be investigated by photography, carrying the work to objects as faint as can be reached with large instruments, in accordance with Kapteyn's 'Plan of Selected Areas' or some equivalent. For this purpose, it is essential to have a set of reference stars, distributed uniformly over the sky, and of suitable brightness to serve as photographic standards, and to make the observations strictly differential with respect to these,

* This statement has been criticised as too broad, but inasmuch as all geological phenomena depend upon elevation above sea level and elevation is shown to be due to reduction of density, then the statement is justified. Volcanic action is only the last expression of reduction of density.

using them not merely as reference points for position when reducing a single plate, but as reference points for proper motion when comparing two plates of different epochs. The observations of these reference stars must at present be made with meridian circles; but the proposed methods for determination of absolute positions of the stars by photography deserve careful study and trial.

Pending the completion of such a program, the investigation of the proper motions of faint 'optical' companions of bright stars, such as has been made by Comstock,[53] furnishes our best source of information concerning the proper motions of faint stars, but is complicated by systematic errors in the early measures. A survey of the whole heavens for stars of large proper motion is very desirable. In this case it is legitimate to treat the general 'background' of stars as at rest, and the observations can be very rapidly made, with the blink microscope or similar appliances. Early plates are probably already available for almost, if not quite, the whole of the heavens. Such an investigation is likely to yield important information concerning the stars of very small absolute luminosity—as is shown by Barnard's[54] and Innes's[55] recent remarkable discoveries—and should be extended to the faintest accessible stars.

Comparison of measures of plates taken at different epochs (still treating the bulk of the stars as fixed) will yield much information about proper motions of moderate size. This has already been done on an extensive scale with plates of the Astrographic Catalogue.

Special investigations should be made to determine at an early date the proper motions of all stars belonging to certain interesting classes for which early determinations of position are available—for example, binaries, variables, and stars having peculiar spectra.

7. The study of the *radial velocities* of the stars is intimately associated with that of the proper motions. The determination of radial velocities with the slit spectroscope has been brought to a high degree of perfection, but the separate investigation of each one of the many thousands of stars which are now accessible would involve an enormous amount of labor. The development of some method by which radial velocities could be determined *en masse* with the objective prism would be a great boon. If some absorbing medium giving sharp and well distributed lines in the blue and violet could be found, the problem would become simple; and other solutions are doubtless possible.

It is also desirable that some method be devised for obtaining, at least aproximately, the radial velocities of stars possessing spectra with very diffuse lines. At the present time, no radial velocities have been published for some of the very brightest stars, on this account.

In extending the list of observed radial velocities, much advantage

[53] Comstock, G. C., *Astron. Journal, Albany*, **25**, 1907, (119).
[54] Barnard, E. E., *Ibid.*, **29**, 1916, (181).
[55] See summary in *Monthly Not. Roy. Ast. Soc.*, **78**, 1918, (304).

has been gained by a policy of selective observation of classes of stars of special interest—such as stars of unusually large and small proper motion, absolute magnitude, and the like, variable stars, and stars of the rarer spectral types. A similar investigation of double stars showing evidence of physical connection would be worth while.

8. Statistical discussions of the motions of the stars and of the Sun, and their relation to spectral type, etc., offer an extensive and very intricate field. Among the matters demanding further investigation may be mentioned the reason for the differences in the direction and velocity of the solar motion derived from stars of different spectral types, and from proper motions and radial velocities separately; the origin of the constant term in radial velocities (Campbell's K term); the existence of tendencies toward common motion among the stars in particular regions of the sky; the dependence of the mean peculiar velocities of the stars upon spectral type and absolute magnitude, and the real cause of this dependence (possibly a correlation between large velocity and small mass); the true nature of preferential motion, and whether it really gives evidence of the existence of two physically different 'streams;' the dependence of preferential motion upon spectral type, absolute magnitude (the latter an unworked field) and perhaps upon the region of the sky considered; the devising of a rapid method for the detection of moving clusters, and the identification of their members; and so on. The discussion of most of these problems should be based simultaneously on proper motions and radial velocities. Results derived from either one alone may fall into errors which the combination of both would detect.

One practical matter deserves specific mention. When it appears desirable to exclude certain stars from a statistical discussion (for example, those of very large proper motion), the limits of exclusion should be clearly and precisely stated. Neglect to do so may cause great trouble to other workers who wish to make a comparison with their own results, and has sometimes led to very serious errors of interpretation.

9. Another set of data of fundamental importance depend upon relations involving the *masses* of the stars. Here there appears the grave difficulty that nothing at all can at present be found out concerning the mass of a star unless it is double. There are plenty of double stars, to be sure; but what certainty have we that they are similar in mass to stars which are not double? Only an indirect answer is possible, by means of the statistical comparison of single and double stars with respect to as many characteristics as may be—absolute magnitude, spectrum, color, radial velocity, proper motion, distribution in space, etc. (bearing in mind that the limits of telescopic resolution restrict our knowledge of the remoter pairs). But Eddington's recent theoretical researches[82] lead to the hope that it may some day be possible to

[82] Eddington, A. S., *Monthly Not. Roy. Ast. Soc.*, **77**, 1916-17, (16 and 596); also *Astrophys. Jour.*, **48**, 1918, (205).

estimate the mass of any star when its absolute magnitude and spectral type are accurately known (using the data for double stars as a guide).

(a) As regards the determination of the masses of individual stars, it should be borne in mind that, for statistical purposes, a pair in which the relative motion of the components is known, though the motion in angle may be only a few degrees, is very nearly as valuable as one which has completed a revolution—while a pair for which the relative motion is unknown is of no use at all. The slowly moving pairs which are often, but inaccurately, described as 'fixed,' possess an importance exactly analogous to the stars of small proper motion, and give us invaluable information about those stars which are bright in proportion to their mass—the giant stars, in fact. Now that the discovery of double stars is apparently in sight of completion, it is to be hoped that more attention may be given to the problem of determining the relative motion in as many systems as possible.

(b) The existing data suffice to show that the masses of the stars differ from one another less than any other of their characteristics—the whole range among well determined masses being from 20 times the Sun's mass to one-sixth of the Sun's, which may be compared with a range in luminosity of at least ten million fold. For this very reason, very careful observations are required to enable us to say with certainty that one star is more or less massive than another. It appears certain that the stars of spectrum B are unusually massive,[56] and there is sufficient evidence to show that, in general, stars of great luminosity are more massive than those of small absolute brightness, and that, among the dwarf stars, those of 'later' spectral type are of smaller average mass.[57] But there are very few cases in which we can be sure that a given star is more or less massive than the average for its type.

It is very desirable to determine how great is the range of difference among the masses of stars of similar spectral class or absolute magnitude. Extremely precise determinations of parallax will be needed if this problem is to be solved, but the effort will be well worth while. Sufficiently reliable values of the mean masses of stars of different groups have already been determined, to make it possible to estimate the parallaxes of all but the nearer binaries and 'physical pairs' more accurately than they can at present be observed.[57] This should be of aid in the interpretation of other statistical studies of double stars, such as the proportion of double stars among all the stars of a given magnitude, the relative numbers of close and wide pairs, etc.

The determination of the relative masses of the components of binary systems will soon also be possible in many cases which have previously been some what neglected.

When a sufficient number of accurate determinations of mass have

[56] Ludendorff, H., *Astron. Nach.*, **189**, 1911, (145-155).
[57] Russell, H. N., *Pop. Astron.*, **25**, 1917, (666).

been made, a detailed study of the spectra of stars differing in mass should be made, in the hope of finding peculiarities depending directly on the mass, which might make it possible to estimate the masses of isolated stars.

(c) A great number of *spectroscopic binaries* await investigation, and more are continually being discovered. In the determination of orbits, preference should be given to those which show the spectra of both components, as it is only in this case that definite information can be obtained about the masses. Eclipsing and Cepheid variables are also worthy of special attention, and also stars of large proper motion, or others which appear to be dwarf stars.

It is very desirable that some method should be found for observing the spectrum of the secondary component when it is too faint to be directly seen. Perhaps Koch's spectromicrometer might furnish a solution. Favorable cases for trial, in which the brightness of the invisible secondary spectrum is known, may be found among eclipsing variables.

10. The *densities* of stars can so far be determined only when they are eclipsing variables. In this case, when both spectra can be photographed, the *diameters* of the components can also be found. Several systems of this sort, which have not yet been investigated spectrographically, are within the reach of existing instruments.

If, however, the relations between spectral type, color index, and surface brightness can be so well determined that it is possible to estimate the last of the three when the other two are known, it will then be possible to determine the densities of all visual binary stars, the linear diameters of all stars of known parallax, and the angular diameters of all the stars in the sky. The known eclipsing variables should afford sufficient material for a first investigation of the problem, if only sufficiently accurate information can be obtained regarding the color-equation of the visual and photographic methods of observation which have been employed at various observatories.

11. All that can be said at present regarding the *internal constitution* of the stars depends on Eddington's theoretical work,[82] which indicates that, in the stars of low density, the mass should be greatly condensed toward the center—the central density being 54 times the mean density. But the problem is capable of investigation by observation. There are many close eclipsing pairs in which the components are ellipsoidal in form, as is proved by variability of the Beta Lyrae type. In such systems the lines of apsides of the orbits should advance, at a rate depending on the masses, dimensions, and internal constitution of the components. If the last is like that of Jupiter or Saturn, the advance of periastron should be rapid. What little evidence there is indicates a slower motion, and hence a very strong central condensation; but more intensive studies are necessary before definite conclusions can be drawn. There are several systems for which the necessary data concerning the dimensions and forms of the orbits and the stars

[82]See footnote p. 266.

are accessible to suitably planned observations,—notably α Virginis and *U* Herculis. A careful study of such stars, by means of simultaneous photometric and spectroscopic observations, would be remunerative.

The singular and so far inexplicable changes which occur in the periods of most eclipsing variables, and so far have defied prediction, also deserve extended study; and Eddington has recently called attention to the fact that secular changes in the periods of Cepheid variables are likely to give a clue to the rate of stellar evolution.[58] The first scanty evidence points to a very extended time scale.

12. In the investigation of *star-clusters,* measures of position, for the purpose of detecting future proper motions, are obviously a duty to posterity. There is little chance that anything more than the motion of the clusters as a whole will be perceptible in our generation, and only measures of the utmost attainable accuracy and freedom from systematic error are likely to be of use to the astronomers of the future. Of far more promise are studies of the distribution of the stars within the clusters, their magnitudes, and, above all, their color indices. Such investigations, in Shapley's hands,[59] have given us for the first time a true conception of the distances and magnitudes of the globular clusters. Students of the subject are eagerly awaiting the detailed publication of the evidence on which he bases his conclusion that the apparent avoidance by these clusters of the region within 1500 parsecs of the galactic plane is due to a real absence of clusters from this region, and not to obscuration by absorbing matter.

The variable stars in clusters also deserve further attention. Those so far discovered appear to belong to the Cepheid type, which is natural, as these seem to be actually the brightest of all variables. Long period and eclipsing variables may yet be discovered among the fainter stars.

Good work can still be done also upon the irregular clusters,—as is shown by Trümpler's[60] study of the outlying members of the Pleiades.

One of the most attractive of unexplored fields is the investigation of the *Magellanic Clouds.* The small amount of work which has been done,mainly on the Smaller Cloud, has led to the discovery of a remarkable relation between the periods and absolute magnitudes of the variables in the Cloud,[61] to the estimate that its distance is 20,000 parsecs,[62] and to the discovery that the nebulae within it, and probably the Cloud as a whole, have a very high radial velocity.[63] The great instruments which are now being erected in the southern hemisphere may well be actively directed toward this region.

13. *(a)* Foremost among the many problems presented by the

[58] Eddington, A. S., *Monthly Not. Roy. Ast. Soc.*, **79**, 1918, (19).
[59] Shapley, H., *Astrophys. Jour.*, **48**, 1917-18, (89-124, 154-181).
[60] Trümpler, R., *Pop. Astron.*, **26**, 1918, (9).
[61] Leavitt, Miss H., *Harvard Circular*, **173**, 1912.
[62] Shapley, H., *Astrophys. Jour.*, **48**, 1918, (155).
[63] Wilson, R. E., *Pub. Ast. Soc. Pacific*, **27**, 1915, (86).

gaseous nebulae is the cause of their luminosity. In spite of our ignorance of the origin of the characteristic nebular lines, the appearance of such lines as λ 4686 in the spectra of nebulae, and of the Wolf-Rayet spectrum in their nuclei, suggests that in them "we are presented" (in Fowler's words)[64] "with phenomena which result either from the effects of powerful electrical actions or of very elevated temperatures." Though such conditions may easily enough exist in the nuclei, it is very hard to see how high temperatures can prevail throughout the whole volume of a nebula.* There are several possible ways out, however.

The electrical action may be a bombardment of the outer region by corpuscles emitted from the nucleus. Or perhaps the luminosity of the gases is fluorescent, like that of the sodium or bromine vapors studied by Wood.[66] Or, as Fabry has recently suggested,[67] we may have to do with a body which absorbs and emits radiation only in narrow regions of short wave-length, and may therefore attain a very high temperature in thermal equilibrium with the radiations from a distant, but still hotter, source. To determine the true explanation among these and many other possibilities may tax the resources of both experimental and theoretical spectroscopy.

The association of gaseous nebulae with stars of 'early' spectral type might be anticipated on any of these theories. For such stars are very hot bodies, and would be the most powerful sources both of corpuscular and ultra-violet radiation. Hence the association of these stars with nebulae does not prove that the stars originate from the nebulae. It is entirely conceivable that, on the contrary, the nebulae, as visible objects, owe their existence to the radiation of the stars, and are their offspring, and not their parents. Some gaseous nebulae, however, are not near bright stars, and the nuclei of planetary nebulae appear to be comparable with some of the faintest stars in luminosity. Clearly, nothing final can be said on this subject until we know what it is that shines in the gaseous nebulae, and why. It may be remarked, however, that the wide-spread assumption that the origin of the stars is to be sought in the visible nebulae appears to have had very little solid basis. All classes of nebulae except the extended gaseous nebulae have already been excluded from consideration as observational knowledge increased.

(b) A few nebulae, like those in the Pleiades,[68] appear to shine by light reflected from neighboring stars, and Slipher's spectroscopic work is steadily adding to the list of his discoveries in this field. Hertz-

* Fabry's calculated temperature of 15,000° for the Orion Nebula,[65] as he points out, is liable to be diminished by an unknown amount on account of the widening of the lines of the spectrum by turbulent motion of the nebular matter in the line of sight.

[64] Fowler, A., *Monthly Not. Roy. Ast. Soc.*, **77**, 1917, (516).
[65] Fabry, *Astrophys. Jour.*, **40**, 1914, (256).
[66] Wood, R. W., *Physical Optics*, 2d ed. (New York, 1911), p. 583.
[67] Fabry, *Astrophys. Jour.*, **45**, 1917, (269-277).
[68] Slipher, V. M., *Lowell Observatory Bulletin*, **2**, 1912, (24).

sprung[69] has shown photometrically that the brightness of the nebulosity in the Pleiades is entirely consistent with the reflection hypothesis. Similar studies of other nebulae, and especially of the remarkable variable nebulae recently observed by Slipher,[70] would be of value.

Barnard's long continued researches[71] have made it highly probable that there exist many *dark nebulae,* revealed only by the effects of their opacity in concealing whatever lies beyond them. It is highly significant that the most remarkable of these dark regions is obviously directly connected with one of the nebulae which shines by reflected light,—that surrounding Rho Ophiuchi[72]—and that the whole mass is comparatively near us in space, at a distance of 100 to 150 parsecs. If such masses of practically opaque material are scattered through the galactic and extra-galactic regions at distances comparable with this, the resulting absorption of light must play a very important rôle in limiting the apparent extent of the universe. If this absorption is of the type which is produced by dust, or even by particles of the size of the drops of water in ordinary clouds, it will affect all wave-lengths to substantially the same extent, and be much more difficult to detect than the gaseous scattering, increasing for the shorter wave-lengths, which several investigators have sought for, but whose existence Shapley has apparently disproved.[22] It seems appropriate to remark in this connection that absorption independent of the wave length seems *a priori* much more likely to occur than the other, since the same quantity of matter in the form of a fog is incomparably more effective than in gaseous form, (compare the opacity of a few meters of cloud with that of all the rest of the atmosphere) and also since most forms of matter are likely to be in the solid or liquid state at the temperatures prevailing in interstellar space.

(c) The forms of nebulae—especially of planetary and ring nebulae—deserve careful study. As Campbell suggests,[73] it is difficult to account for them without assuming the existence of some repulsive force which counteracts the attraction of the nucleus. He suggests light-pressure—which would fit in well with views of the origin of the luminosity such as are suggested above. In such a case we should anticipate that most of the light of the nebulae would come from the nucleus, and this appears to be usually, though not always, the case.

(d) Measures of the radial velocities of nebulae have already shown that the planetary nebulae, as a class, are moving in space much more rapidly than the stars;[74] that there exist internal motions within them, usually of a rotational character, but sometimes more complicated;[73] and that, in order to keep the moving material from flying away into

[69] Hertzsprung, E., *Ast. Nach.*, **195**, 1913, (449).
[70] Slipher, V. M., *Lowell Obs. Bull.*, **3**, 1918, (63).
[71] Barnard, E. E., *Astrophys. Jour.*, **49**, 1919, (1).
[72] Slipher, V. M., *Lowell Obs. Bull.*, **2**, (155).
[73] Campbell, W. W., *Pub. Ast. Soc. Pacific*, **29**, 1916, (284).
[74] Campbell, W. W. and Moore, J. H., *Ibid.*, **27**, 1915, (240).

space, the total masses of the nebulae must be very considerable, and probably a good deal larger than those of the stars.[73] Much remains to be done in the investigation of these motions, and in their interpretation. The proper motions of planetary nebulae, and perhaps in some cases the internal motions of the nebular material, can be determined by comparison of suitable photographs, and it is probable that in a decade or two we shall obtain in this way a fair idea of the distances and real dimensions of these bodies. Observations for parallax on some of the larger and presumably nearer planetary nebulae are also desirable.

The extended gaseous nebulae should be examined spectrographically to see whether turbulent motions exist in others, as they do in the great nebulae of Orion;[75] and it would be worth while to compare photographs of some of those which show sharp details, in the hope of detecting proper motion, either of the whole or of parts.

Investigations of the distribution within the gaseous nebulae of the substances which give the different spectral lines may be made by photography either with absorbing screens or with slitless spectroscopes, and promise information regarding the conditions prevailing in the nebulae, and the mutual relations of the lines of unknown origin.

14. *(a)* The *spiral nebulae* have been shown by recent investigations to be the most extraordinary objects in the heavens. Their enormous radial velocities—first detected by Slipher[76]—and the almost equally rapid internal motions within them,[77] put them in a class by themselves. Further measures of these motions are needed; and, when the radial velocities of a sufficient number of spirals, well distributed over the heavens, are known, it may be possible to determine definitely the direction and rate of the motion of the Sun (and presumably of the whole galactic system) with respect to the system of nebulae. The provisional determination by Young and Harper,[78] from very scanty data, indicates for the motion of our system the enormous velocity of 600 kilometers per second.

(b) As van Maanen[79] and others[80] have shown, the proper motions of some spiral nebulae—both of the mass as a whole and of the condensations in the arms relatively to the center—are apparently large enough to be determined by the careful comparison of plates taken only a few years apart. This opens up another wide field of study, and will make it possible before long to determine the mean parallax of many such nebulae by comparison of the proper motions and radial velocities of their nuclei. There is also reason to hope that the distances of some individual nebulae, which are seen at a suitable angle, can be deter-

[73] Fabry, *Astrophys. Jour.*, **40**, 1914, (241).
[76] Slipher, V. M., *Pop. Astron.*, **23**, 1915, (23).
[77] Slipher, V. M. *Lowell Obs. Bull.*, **2**, 1914, (66).
[78] Young and Harper, *Jour. Roy. Ast. Soc. Canada*, **10**, (134).
[79] van Maanen, A., *Astrophys. Jour.*, **44**, 1916, (210-228).
[80] Kostinsky, S., *Monthly Not. Roy. Ast. Soc.*, **77**, 1917, (233).

mined by comparing the radial and transverse components of motion along the arms. Enough is already known to convince us that the distances of these nebulae must be measured in thousands of parsecs, and their diameters in parsecs, and that direct measures for parallax are utterly hopeless.

(c) Photometric measures, both of the total light of the spirals and the relative brightness of their parts, would be of value, especially if accompanied by determinations of color. Seares[81] has recently shown that the outer convolutions are far bluer than the center—which is the part that shows the spectrum of solar type. Spectroscopic observations of these outer regions, if possible, would be of great interest. Another matter calling for further study is the nature of the dark bands which cross many nebulae which appear to be spirals seen edgewise, and look as if they were due to the interposition of opaque material in the outer regions of the nebula.

(d) The distribution of spiral nebulae in the heavens—so utterly different from that of any other objects—may be explainable when their real distribution in space is even partially known. It is hardly time as yet to consider the greater question of their real nature, except to note, with van Maanen,[70] that, unless they are in process of very rapid dissipation into space, their masses must be exceedingly great.

15. Finally, it must not be forgotten how important a place *theoretical investigations* will occupy in the solution of the larger problems of sidereal astronomy. The increasing observational data are already furnishing just those guides which point the skilled mathematician in the right direction, and these indications have been very successfully followed, especially by certain members of that 'Cambridge school' which combines keen mathematical analysis with a thorough knowledge of modern physics. Results of remarkable generality have already been obtained.

In the field of stellar evolution, Eddington[82] has worked out in detail the importance of radiation pressure in determining the conditions of internal equilibrium of the stars, and the approximate equality in brightness of the giant stars of all spectral types has found a simple explanation.

If the conclusion that the luminosity of a giant star is a function of its mass, but not of its temperature or age, is confirmed, and the nature of the function fixed by observation, the problem of determining the masses of stars which are not double will in many cases be solved.

Jeans,[83] discussing the problem of the figures of equilibrium of a rotating mass of compressible fluid, has already reached conclusions which not only bear upon the origin of double stars, but have suggested an entirely new and very stimulating conception of the nature of spiral nebulae, as huge rotating masses of gas, which, becoming unstable at

[81] Seares, F. H., these *Proceedings*, **2**, 1916, (553).
[82] Jeans, J. H., *Observatory*, **40**, 1917, (60).

the edge under the influence of their own rotation and the attraction of the neighboring stars, throw off matter from their periphery in streams of such enormous size that they may divide into 'nuclei' large enough to form ordinary stars upon condensation.

In the field of galactic astronomy, Schwarzschild[84] has developed powerful methods for handling the statistical material which must be our main guide, and Jeans[85] and Eddington[86] have shown that 'star streaming' demands no unknown forces for its explanation, but is probably interpretable dynamically, as a property of a system of stars in motion under their own gravitation—although the existence of 'streaming' appears to indicate that the galactic system is not in a 'steady state.' Eddington[87] has shown that the similarity of distribution of the stars in different globular clusters presents a problem by no means simple, though of much interest.

Almost the whole of this work has appeared within the last three years, and further notable advances may be anticipated. Indeed, almost as these words are written, comes the first installment of an important paper by Eddington[88] on the oscillations of a gaseous star, which may afford the long-sought solution of the problem of Cepheid variation.

Among other specific problems awaiting discussion may be mentioned the question whether the tidal interaction of two compressible and slowly condensing bodies can cause an originally small eccentricity to increase to the very large values which are found in many visual binaries, and some spectroscopic binaries as well; and, if this proves to be impossible, how the systems in question can have originated;[89] the origin and laws of the complicated changes which occur in the periods of many eclipsing binaries; and the equilibrium and motions of the constituent parts of planetary and spiral nebulae.

Mention should also be made of the work of Nicholson[90] on the interpretation of unknown lines in the spectra of nebulae and of the solar corona as arising from hypothetical atoms of very simple structure—which has successfully met the test of prediction—and of the development of the theory of general relativity, which has already been used by deSitter[91] to set a superior limit to the whole quantity of matter in the universe, and may have important applications in future.

16. Of more fundamental nature and obvious importance, is the unsolved problem of the source of the energy which the stars are continu-

[84] Schwarzschild, K., *Astron. Nach.*, **190**, 1912, (361), and **198**, 1914, (217).
[85] Jeans, J. H., *Monthly Not. Roy. Ast. Soc.*, **76**, 1915-16, (70 and 552).
[86] Eddington, A. S., *Ibid.*, **74**, 1913, (5), and **75**, 1916, (366), and **76**, 1916, (37).
[87] Eddington, A. S., *Ibid.*, **76**, 1916, (572-585).
[88] Eddington, A. S., *Ibid.*, **79**, 1918, (2).
[89] Nolke, F., Abh. Nat. Ver. Bremen, **20**, Teil 2, 1911, (193-220). Jeans, J. H., *Observatory*, **42**, 1919, (40).
[90] Nicholson, J. W., *Monthly Not. Roy. Ast. Soc.*, **76**, 1916, (415); **78**, 1918, (349), and earlier papers.
[91] deSitter, W., *Ibid.*, **78**, 1917, (25).

ally radiating at so rapid a rate. It is becoming increasingly plain that the gravitational energy liberated by contraction from infinity would not nearly suffice to maintain the Sun's radiation during geological time[90] (according to even the more conservative estimates of the latter); yet the mere continuous existence of life on the Earth is evidence that the Sun has not merely kept on shining throughout this interval, but has not changed in brightness by more than one magnitude, at the outside. In the case of some giant stars, contraction from infinity would hardly suffice to furnish the energy which they have radiated during historic time.[91] There appear to be two ways out of the difficulty; either the stars do not radiate heat in all directions to space at the same rate as they do towards the Earth, or else they have some unknown and exceedingly great supplies of internal energy. The first alternative, however, seems to be excluded by the fact that the amount of heat which the Earth receives from the Sun, and loses again by radiation into space, is not greatly, and probably not at all, inferior to that which a black body of the same size and temperature as the Earth's effective radiating surface would radiate to an enclosure at the absolute zero.[92] There seems therefore no escape from the conclusion that the heat radiated by a star can not be provided by contraction. What the source of the energy may be, how it is converted into heat in the body of the star, and where it goes after passing from the star's surface into the ether, are at present the greatest of all the unsolved problems of astronomy.

FIRST STUDY OF HEAVENLY BODIES.

By MARY E. BYRD.

Lesson V.

The appropriate time has come to count up our treasures, the observations of sun, moon, planets, and stars that have been reported but not yet considered in detail. And first in order is the sun. A brave beginning has been made on the long series of diurnal paths which is our main dependence in unraveling the tangled web of the seasons. Two of them received from L. E. B., Kansas City, Mo., are fixed by the key positions, noon and setting points, while the third has the merit of including the sunrise point, and thus indicating the connection between the place of the sun when rising and setting. This statement is purposely left a little vague so as not to filch from anyone the pleasure of individual discovery.

[90] Shapley, H., *Pub. Ast. Soc. Pacific*, October, 1918, (283-298).
[91] Eddington, A. S., *Monthly Not. Roy. Ast. Soc.*, **79**, 1918, (19).
[92] Abbot, C. G., these *Proceedings*, **4**, 1918, (104-106).

The other three paths in the list are by A. L. P., Fall River, Wis., who has had the advantage of some preliminary experience in practical exercises. He employed a window gnomon in obtaining the altitude and azimuth of seven or eight points in each path, plotted them on rectangular paper, and then through the points drew smooth curves which show at a glance the form of the paths and their relation to zenith and horizon. Both these observers have evinced skill and ingenuity in constructing and testing their own apparatus. It is also perhaps worthy of note that their stations are separated by 4 degrees in latitude, and so every one interested in first study of the heavens is cordially invited to explain how, on the same date, this difference would affect the sun's noon altitude and points of rising and setting. And what about the equinoxes?

Even so august a body as the sun may be pressed into service in finding time, and by far the most important solar observations received are noon transits of the sun. There are four of them, taken by A. L. P., though as these are the first he has taken, one or more should be set aside as simply for testing and experimenting. That of March 18 is given in full on a later page of this lesson.

Since the moon's path through half the constellations of the zodiac was discussed in Lesson III, lunar observations have not bulked large. A few good positions have been sent in but more are needed, for surely we want to find out whether, month after month, the moon goes by the same stars, and about the other half, the unexplored part of its path.

Conditions for seeing the new moon apparently have not been favorable, at least the following account, obtained rather late, is the only one that has come to hand:

"2509 Askew Ave., Kansas City, Mo., Wednesday, Feb. 25, 1920. On the 19th of the month the moon was new, but owing to prevailing cloudiness it has not been visible here until tonight when it is less than 24 hours from first quarter and the crescent is approaching a semi-circle.

"It shines with a silvery-white light, and I note that it is not of uniform brightness, but shows irregular markings near the center of the crescent, along the terminator, which are darker than the rest of the illuminated portion. The cusps are of uniform shape and turned away from the sun. The terminator appears as a smooth, unbroken line." L. E. B.

For the two planets which this year we call ours, Jupiter and Mars, the outlook is bright that the course of the first among the stars will be traced for half a year and for the other during the whole year. Already 9 positions have been reported for Jupiter, 7 by S. H. C., St. Mary's Convent, Notre Dame, Ind., and 2 by A. L. P., who is making so many observations. He is certainly to be congratulated on proving motion for this slow-going planet within 4 days, and to him also belongs the credit of 4 well-distributed points fixed for Mars. To these a welcome addition is made by a 5th point, located by L. E. B., Kansas City, Mo., when he was establishing the identity of Mars; for he too has determined without doubt what bright object in the sky is the

planet Mars, thoughtfully choosing the propitious date, Feb. 10, when this body and the moon were in conjunction.

Not sun, nor moon, nor planet, however, appeals to many as the stars do. From West Brighton, N.Y., J. C. B. reports with a glow of enthusiasm the view had on a winter's night of Orion and its nebula; an account of the wide double, ζ Ursae Majoris, as seen with the unaided eye and with field glasses, is given by L. H. J., Greensboro, N. C.; and one who says of himself he is a beginner, studying only for the good of his soul, W. B. M., Wallsend, Ky., writes, "From the February and March numbers of POPULAR ASTRONOMY I have succeeded in identifying nearly all the constellations and the most conspicuous star in each, and now at sight I am able to recognize any one of them." Good descriptions of Leo, and Canis Minor, and a thoroughly satisfactory identification of Lepus with alignments and diagram have come from L. E. B., already mentioned more than once.

Others might well be included. Room at least must be given to this query: "Could one at some hour of the night identify an aspect of the stars as belonging to the 9 o'clock position by saying I am looking at an April sky, say at 11 o'clock in March, or at a May sky, at 1 o'clock in March?"

Who will put the question to the test, keep patient watch and find if indeed there is a June date when at 9 o'clock the constellations are placed just the same in reference to zenith, meridian, and horizon as at 11 o'clock on a certain date in May? And who then will give the exposition?

The new subject that confronts us in this lesson, one that cannot longer be postponed, is about as grim and difficult of approach as a fortress set on a hill. It lends itself in nowise to purple-adjective thrills, no writer on popular astronomy takes it for his theme. He would about as soon think of entertaining his readers by discoursing on the calculations involved in predicting local occultations of stars by the moon! And yet is it true that the student actually taking the observation required finds it anything but prosaic.

Turn back a little the tide of years and come with me in imagination to a laboratory for elementary astronomy. Its furnishings, the bulletin boards for appointments, star-maps, tables of logarithms, ephemerides, celestial globes, and other appliances for reducing and checking observations need not concern us now. It is evening, the electric lights are out, students, not a few of the eighty whose workroom this is, pass back and forth from time to time, and climb in and out of the west window which leads to their observing station on the adjoining roof.

At the south window, by a large projecting board, dimly seen by the light from the street below, stands a dark-haired Jewish girl, with her gaze nervously fixed on two plumb lines, adjusted in reference to a line on the board. The instructor seated near by with watch in hand also appears solicitous in giving final directions. "Be sure you are holding

your head so that the lines appear as one, if β Orionis is still a little distance away, rest your eyes a few moments by closing them without moving the head, however. If possible give me a little warning beforehand and call "tip" rather than "time."

And so our little secret is out. The grim problem is "time", and the question to be answered is "How can the Hebrew maiden find time, that is, ascertain how many seconds her watch is fast or slow by noting the instant when a star crosses the meridian? That sounds simple, does it not? And yet to answer fully there would be need almost to write a book! Here, nothing more can be attempted than to deal with the problem in its bold outlines, passing over many details and taking on trust not a few statements in text-book and Ephemeris. It will also be the part of wisdom to make first the reduction for the transit of the sun rather than for a star. Even then three kinds of time are involved, apparent, mean, and standard. And what are they? Apparent or sun time is that controlled by the sun in the sky. The instant when it crosses the meridian marks apparent noon, and at any moment its hour-angle is apparent time. This sun time was long employed and the world was loath to part with it, even after clocks were made that kept better time than the sun. Retaining it, however, necessitated such constant manipulation of the clock, putting it forward and backward, that the effort had to be abandoned, and instead recourse was had to mean solar time (Howe's Elements of Descriptive Astronomy, § 125). This is controlled by an imaginary body, called the mean or fictitious sun which moves in the celestial equator at a perfectly uniform rate and completes the circuit in just a year. Mean local noon, then, is the instant when this fictitious sun crosses the local meridian, and its hour-angle reckoned from that meridian is at any moment local mean time (Young's Elements, Art. 55).

Fortunately this time differs at most only about a quarter of an hour from apparent time and the change from one to the other is readily made by means of the difference between the two (Young's Elements, Art. 128). This is called the equation of time and is constantly changing but so slowly that, in observations considered here, the noon value, given daily in the Ephemeris for Washington, may be used through the day and throughout the country. In applying the equation of time, the signs prefixed are to be taken in the sense that apparent time is fundamental and mean time is derived from it by adding the quantity to apparent time when the sign is plus and subtracting it when the sign is minus (Byrd's First Observations in Astronomy, §§ 36, 37).

Though the term equation of time is not used in the small almanacs, it is often given there as "sun fast" and "sun slow" where the words fast and slow replace the signs minus and plus. This simple precept does not hold, however, in the Old Farmer's Almanac.

Ah, if we could only stop here, it might be possible to enter a defense of time after all, but the end is not yet. In the latter part of the

last century, local mean time for various reasons was adjudged unsatisfactory (Young's Elements, Art. 65), and in 1885 standard time was adopted. Probably we ought to be thankful that a third sun was not foisted upon us. Instead, double duty was imposed on the fictitious sun, for it controls standard as well as local time. The instant when it crosses the standard meridian of a given time section marks standard noon, and at any moment its hour-angle reckoned from that meridian is the standard time of the section. Thus, it follows that exactly at the standard meridian, standard time is local time.

At present standard time is in use in all parts of the world. In North America there are five divisions, known as Colonial, Eastern, Central, Mountain, and Pacific, and their standard meridians, centrally placed, are respectively 4, 5, 6, 7, and 8 hours west of Greenwich. While it cannot be denied that this time facilitates travel, transportation, and communication by railway, telegraph, and airplane (!), no one would claim that it is an advantage in astronomy. For students especially it complicates the subject of time, and yet the changes from one standard time to another, from local to standard, and standard to local, are really not very difficult (Byrd's First Observations, § 38). Since, as just noted, any standard time is the local time of its standard meridian, the three problems are reduced to passing from one local time to another, an exercise that is none other than the familiar one in longitude and time, given in the geographies.

Almost, our goal is reached, for now it is possible to reduce intelligently the following observation for time:

Lone Elm Ast. Station, Fall River, Wis., Thursday, March 18, 1920. Having checked the north and south line already drawn on the projecting board of the solar-image gnomon, I carefully adjust two plumb lines with movable supports, so that the points of the bobs come to rest exactly over the line. Holding the head so that the plumb lines appear as one, I note three times of transit as follows:

	h	m	s
Transit of west limb,	12	3	15
Transit of center,		4	55
Transit of east limb,		5	65
Mean,	12	4	45

Comparison of the watch used was really effected with the time of Washburn Observatory, but as it passed through two telephone exchanges the watch may have been in error several seconds, though when compared it was apparently correct. A. L. P.

Since the watch was set to standard time, the $12^h\ 4^m\ 45^s$ above is the standard time of sun noon, according to the observation; and if one could obtain independently the theoretically correct instant of this noon, in standard time, the difference between the two would be the watch error sought. But how to derive that instant is one of the things shown in the preceding discussion, and for the given observation we proceed thus:

Sun noon in sun time is of course, $12^h\ 00^m\ 00^s$, and this like any

other sun time is reduced to local mean time by the equation of time, which for the given date is $+ 8^m 09^s$ (Ephemeris, 1920, p. 515), making the local mean time of sun noon, $12^h 08^m 09^s$. To find the corresponding standard time, note that the standard meridian of the observing station is the 6-hour meridian W., and the longitude given for its local meridian is $5^h 56^m 48^s$ W. so $3^m 12^s$ is the interval to be subtracted from any local time at the Elm Tree Station to find the corresponding local time at the standard meridian, but that local time is the standard time of the station; and, therefore, the theoretically correct instant of sun noon, in standard time, is $12^h 04^m 57^s$. Now the observed instant, in the same time, is $12^h 04^m 45^s$, and the error of the watch is then 12^s, according to this observation. The following is a concise form for the reduction:

	h	m	s
Sun time of sun noon,	12	00	00
Equation of time,		8	9
Local mean time of sun noon,	12	8	9
Standard Merid. W. of station,		3	12
Stan. T. of S. N. by calculation,	12	4	57
Stan. T. of S. N. by observation,	12	4	45
Error of watch by observation,			12

There is little object in finding time unless there is some way to test the accuracy of the method, and for that reason soon after the sun's transit, the watch was compared with accurate time. This, as explained, involved some uncertainty, but the watch error obtained by observation is doubtless trustworthy well within 20 seconds.

With the exercises given below in the formal topics for this lesson, our "time" story comes to an end. The practical part which later will require further attention is thought to have some ameliorating features!

Topics for Lesson V.

1. Define apparent, mean, and standard noon; apparent, mean, and standard time.

2. Name the standard times in use in our country and give the longitude of the standard meridian of each.

3. If it be assumed, as is usually correct, that any place has for its standard meridian the one that is nearest, what are the standard meridians of the following places? To what time section does each belong? What is the correction to reduce its local to standard time? With what sign is it applied to local to give standard time? Northampton, Mass., $+4^h 50^m 33^s$; Lawrence, Kan., $+6^h 20^m 58^s$; Savannah, Ga., $+5^h 24^m 22^s$; Denver, Colo., $+6^h 59^m 48^s$; San Francisco, Calif., $+8^h 09^m 43^s$.

4. What is the standard time of apparent noon at San Francisco, when the equation of time is $-2^m 59^s$? Give details and explain.

5. In locating the path of the sun in May, find the altitude and azi-

muth of five or more points, including if possible southing, and rising or setting. On the same or some other date, find also as in April the zodiacal constellation nearest the setting point of the sun.

6. *a* and *b*. If there has been no favorable time as yet to describe the crescent moon (Lesson II, 5, *a*,), and locate the moon carefully in reference to neighboring stars (Lesson II, 6, *a*.), try to obtain these observations in May.

c. If both these topics have been taken, examine the moon with opera-glasses, and identify five objects, seas or craters. (Young's Elements, Arts, 173,174).

7. In locating Mars this month, it is desirable to fix two positions, one on an early, the other on a late date, nor should the "five-minute" observations be neglected (Lesson IV, 5).

8. From the data of an actual observation find the place of a planet on Young's Uranography, or better on a celestial globe, if one is available, and derive its right ascension and declination for the date considered (Lesson III, coordinates deduced for the moon).

9. Estimate the altitude of the North Star and explain how this gives a rough value for the latitude of the place (Young's Elements, Arts. 26, 47).

10. Draw a map of the constellation Ursa Major or Cassiopeia.

Mars favorably placed, and visible many hours of the night, especially challenges attention this month.

Route 9, Box 77, Lawrence, Kan.

OUR DEEPEST WELLS.*

Some of the Scientific and Practical Problems Which They May Help Us to Solve.

By ROBERT G. SKERRETT.

The deepest well in the world bored by man is not far from Fairmont, West Virginia, on the J. H. Lake farm. It reaches down into the earth's crust for a distance of 7,579 feet. The goal was a penetration of 8,000 feet to the Clinton sand which, at higher levels in Ohio, has yielded so richly of oil and natural gas.

For years, the well at Czuchow, Germany, of 7,348 feet, stood unapproached, and then our enterprising prospectors for petroleum and gas bored the Goff well in West Virginia about 8 miles away from Clarksburg; and before the last cable broke, leaving a ponderous string of tools at the bottom of the shaft, a depth of 7,386 feet was reached.

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This was in March of 1918, and was the result of 400 days spent in actual drilling.

The Lake well was started in June of 1916, and by September of 1917 had attained a depth of 6,720 feet. Work was halted at that point awaiting a new cable, but the war delayed its receipt, and it was not until the end of October, 1918, that drilling was resumed. This was continued until the 12th of June of last year, when a cave-in far down in the hole put a stop to further operations. On that date the drill had penetrated to 7,579 feet. The cause of the choking was due to a failure to line the bore throughout the lower section, a length of nearly 9/10ths

Thermometers encased in metal frame ready to be lowered into a deep well.

of a mile. The surrounding pressure of the earth and the shock of the heavy percussion drill induced the collapse of the unsupported shaft.

As in the case of the Goff well, the ultimate objective was not attained—a penetration of 8,000 feet; but the man that made the Lake well possible is nevertheless confident that, with a suitable reinforcement of casing, there is no reason why drills should not pierce the earth's shell to a depth of quite 10,000 feet. The practical minded person will ask, "Of what avail are these costly pin pricks, so to speak, into the terrestrial crust which 'according to the book,' has a thickness of something like a thousand miles?"

It seems that the total cost of boring the Goff well was in the neighborhood of $50,000; that of drilling the R. A. Geary well, a few miles away from McDonald, Pa., of 7,248 feet, was $100,000; while the

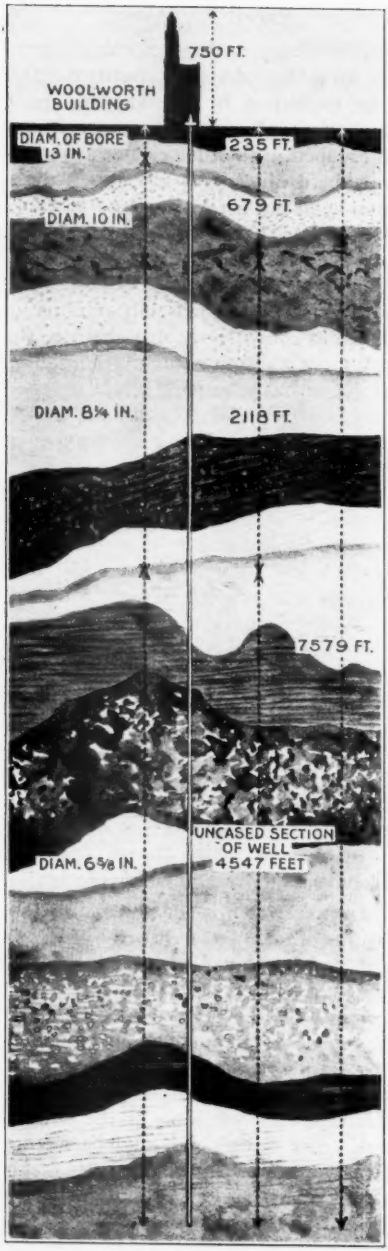
Lake shaft entailed an outlay of approximately $29,000. The differences in expense may be explained by the varying geological difficulties that had to be combatted. A water pressure of nearly 3,000 pounds to the square inch crushed in the tube casing at the bottom limit of the Geary well, burying the drilling tools and effectually stopping penetration into the Clinton sand but a few hundred feet away. But just see what the drilling of that shaft did reveal of potential economic and commercial value.

After the drills had pounded their way beyond a depth of 6,800 feet, they struck layer after layer of rock salt ranging in thickness from 5 to 10 feet, establishing conclusively that these strata extended in unbroken sheets throughout an area of many thousands of square miles. As one eminent geologist has expressed it, "It is barely possible that in addition to the vast quantity of common salt, or sodium chloride, in these great underground deposits, some of the potash salts, potassium chloride, and potassium sulphate, may also exist and will be found interbedded among these other saline products."

There is warrant for the belief that these seemingly unfruitful efforts to obtain petroleum and natural gas have served to disclose the remains of fossil ocean water imprisoned in mid-Paleozoic time, which may make us absolutely independent of Germany in the matter of the potash so essential to the revitalizing of our cultivated acres. But the Geary, the Goff, and the Lake wells are furnishing us a wealth of scientific data of several sorts. Samples of the rock materials, chips of slate, etc., have been studied by the U. S. Geological Survey; and evidences of fossil life from the Goff well were brought to light from a depth of 7,355 feet, while other formations have tended to establish in a wonderful way the harmony of the stratification and wide distribution of the same orders of life over thousands of square miles of the earth's erstwhile surface. These remains of eons gone tell in their mute way of the manner in which the present habitable terrestrial crust has successively been above and below the sea.

The deepest mine in the world is shaft No. 3 of the Tamarack mine, Michigan, which is down 5,200 feet below the surface. The sinking of a mining shaft is limited by human endurance, because the heat of the rocks at a depth of more than a mile is so high that workmen cannot bear up under it even with the help of artificial ventilation. On the other hand, a well can be bored 6 inches in diameter to a far greater depth—penetration depending upon the strength of the cable, the design of the drills, and the skill of the men who "feel" from the ground level just how the far-off tools at the length of the steel line are doing their work. The drills weigh anywhere from one to two tons, and the wire rope maker has proved that he can fashion cables capable of bearing the stresses of lifting and dropping these loads as the tools pound their way downward.

Thanks to the researches of Mr. C. E. Van Orstrand, physical



What the deepest well means in comparison with the Woolworth Building.

geologist of the U. S. Geological Survey, the three deep wells in question have enabled us to find out a number of suggestive things about subterranean temperatures, pointing the way, perhaps, to the practicability of our tapping the earth's vast reservoir of heat for industrial and other purposes. We are told that the center of our globe is composed of an incandescent nucleus ranging in temperature from 3,000 degrees to 180,000 degrees Fahrenheit. These figures, however, have little value, for the U. S. Geological Survey tells us that mathematicians have not yet found the law of the distribution of temperature from the surface to the center of the earth.

It may seem far-fetched, then, to imagine that these deep yet relatively shallow wells will help us to establish this law of distribution, and yet the temperature readings obtained by Mr. Van Orstrand, by means of instruments which he has skilfully devised, may eventually give the world of science the key to Nature's riddle. In the Geary, Goff, and Lake wells, the temperature at a depth of 100 feet is about 55 degrees Fahrenheit. This gradually rises the further down the thermometers are lowered, reaching 142 degrees Fahrenheit in the Geary well at a depth of 6,100 feet; 159.3 degrees Fahrenheit in the Goff well at 7,310 feet; and 168.6 degrees Fahrenheit in the Lake well at a depth of 7,500 feet. The observation at 7,500 feet in the Lake bore is the deepest temperature record yet made.

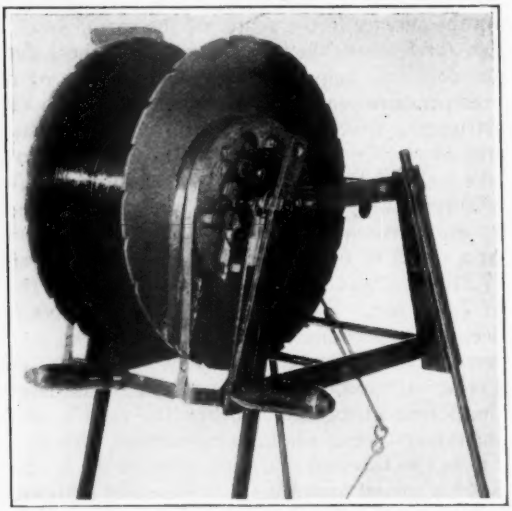
It will be noticed that these readings show variations, which plainly indicate that other circumstances than depth figure in determining the measure of local heat at any point below the earth's surface. This emphasizes the importance of taking temperatures with all possible exactness; and it was to this end that the expert of the U. S. Geological Survey devised his special apparatus. We are told authoritatively that in any of the three deep wells here, which have been under consideration, the boiling point would be reached at a penetration of 10,000 feet.

No one now knows what is the source of the enormous quantity of heat stored away in the bowels of the earth. Some scientists believe it to be due to the disintegration of radium in subterranean rocks; others argue that the earth is a cooling globe radiating heat developed during condensation from the original nebula; while there are those who claim that chemical reactions are responsible. Be this as it may, it may yet be of the utmost importance to us to evolve ways to draw upon this potential energy at will; and the study of the temperatures of very deep wells, and the positive knowledge obtained from these borings of the dip and the successive geological formations lying below our feet are calculated to help us to this end.

In his work in this direction, Mr. Van Orstrand has used two types of temperature registering mediums—so-called maximum thermometers employing a mercury column, and electrical resistance thermometers wherein the deflection of the needle of a Wheatstone bridge indi-

cated the flow of current and, accordingly, the temperature of the resistance element lowered into the well. The trouble with the mercury thermometer is the error that may be introduced by the instrument being jarred during the passage surfaceward, thus shaking down the column of mercury and leading to erroneous records when brought up. Again the mercury thermometer has to be exposed for an hour or so in order to obtain the desired result at the chosen depth.

The electrical resistance thermometer, on the other hand, has all of



The reel for the cable used in sending down the electric-resistance thermometers.

its registering apparatus above ground and it is necessary to lower only the electric circuit. Up to a depth of 3,000 feet, Mr. Van Orstrand's field work has demonstrated the superiority of the electrical equipment. Perfect insulation is necessary, and petroleum ultimately dissolves all of the usual insulating compounds. Therefore, beyond 4,500 feet this physical geologist would have recourse to two sets of three maximum thermometers—one set having the mercury bulbs inverted so that the mercury could not be jarred back into the bulb by any blows transmitted to it on the journey surfaceward. In this way a check would be afforded which would reduce to a considerable measure the likelihood of error.

WHERE THE DAY CHANGES.

By FREDERIC R. HONEY.

The traveler who makes a voyage round the world has the unique experience of apparently lengthening or shortening the year by one day according as he travels east or west. If he travels east, i.e. in the direction of the earth's rotation on its axis, his own motion is added to that of the earth, and the resultant motion is greater than the earth's. As a consequence the sun rises earlier each day, and the length of the apparent day is less than twenty-four hours. But if he travels west, i. e. in a direction opposite the earth's rotation, his motion is subtracted from that of the earth, and the resultant motion is less than the earth's. The sun rises later each day, and the length of the apparent day is greater than twenty-four hours.

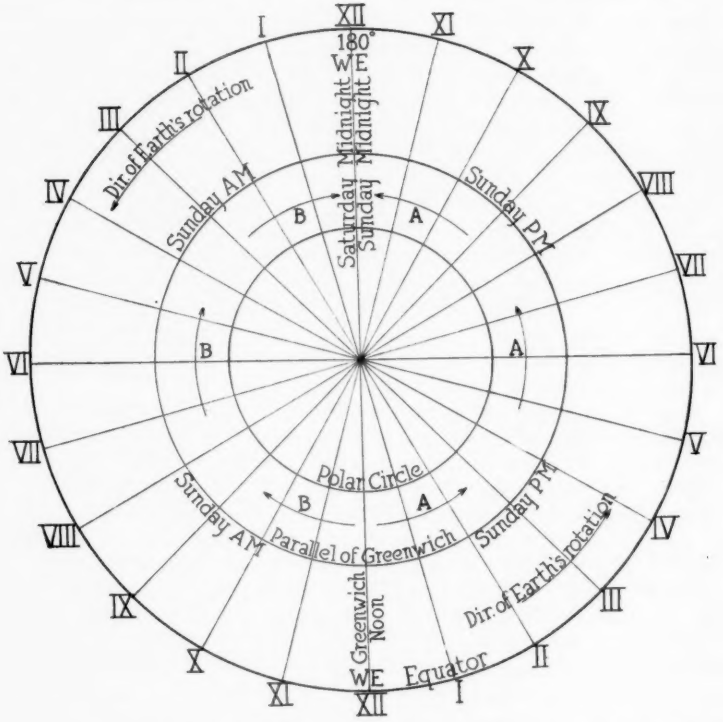
For example, a traveler A, starting from the meridian of Greenwich and going east, reaches longitude 180° east in a certain number of short days; while B, traveling in the opposite direction, reaches 180° west in a certain number of long days. Meeting at 180° E. and W., A and B (whose watches we assume have not been altered during the voyages) discover an accumulated discrepancy in their reckoning of twelve hours each, or a total of one day.

It has been found convenient to make the change of the day at this longitude. This is a suitable meridian because it passes through an area on the earth's surface which is almost entirely covered by water. This is obviously an advantage because it would be impracticable to change the day at a meridian which passes through extended land areas. It would result frequently in next door neighbors adopting different chronologies, and differing both as to the date and day of the week.

Should A return to the meridian of Greenwich by the same route that he came, i. e. in a direction opposite that in which he had traveled —going west instead of east—the apparent day would be lengthened, and the gain of one-half a day would be corrected, on his arrival at the Greenwich meridian, by the loss of half a day. In this event A would observe no change of the day. Similarly if B should return to the meridian of Greenwich in a direction opposite that in which he had previously traveled—going east instead of west—the apparent day would be shortened, and the loss of a half a day would be compensated by the gain of a half a day. In this event also there would be no change of the day.

But if A and B continue their voyages around the world a compromise is made by an exchange of apparent days. By this arrangement A repeats a day, and B omits one.

The drawing is a projection of the earth on the plane of the equator, showing the Greenwich parallel of latitude and circles of longitude at intervals of 15°. The latter may also be taken to represent the hours of the day for one rotation of the earth. To simplify the illustration the sun is assumed to be on the meridian of Greenwich, i. e. it is Greenwich noon. In this position it is the same day—we will say Sunday—all over the earth between Saturday midnight and Sunday midnight, the former corresponding with 180° west longitude ,and the latter with 180° east longitude. Passing from east to west longitude A's time



changes from Sunday midnight to Saturday midnight, and the day is repeated. A has therefore two Sundays in succession. But in passing from west to east longitude B's time changes from Saturday midnight to Sunday midnight, i. e. he omits Sunday from his reckoning.

The illustration is selected for its simplicity. But the change of the day occurs at whatever time the traveler happens to reach 180° east and west longitude. The time is set back or forward twenty-four hours according as he is traveling east or west.

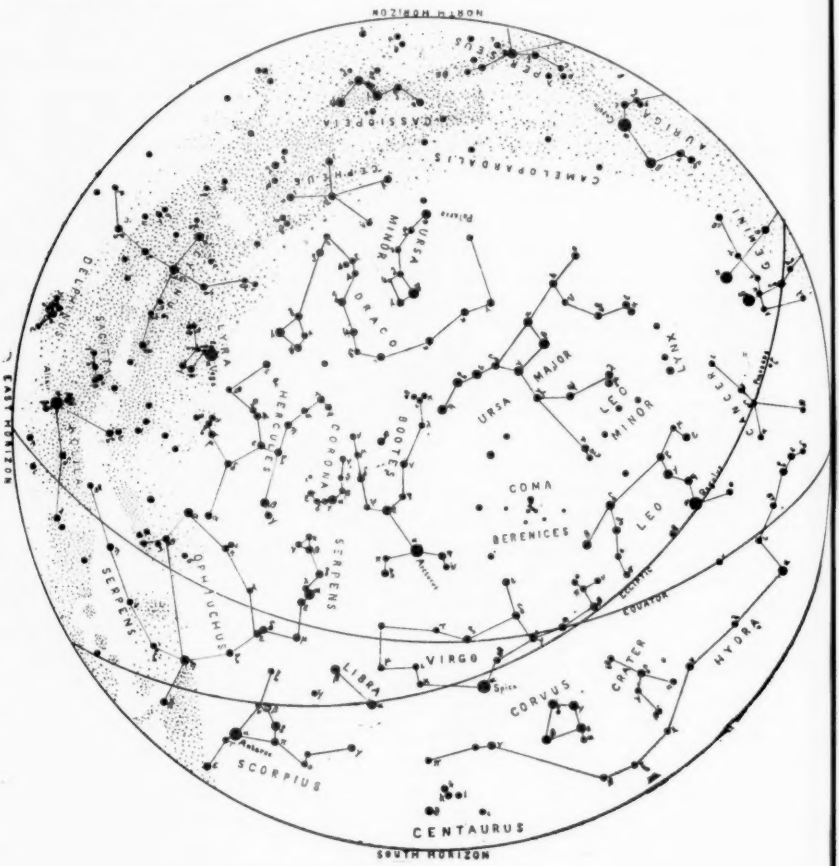
The table shows why a change of the day is unavoidable. Assume that A and B travel at the same speed along a parallel of very high latitude, and that each day A gains on the sun one hour, while B loses one hour. Starting from the meridian of Greenwich, we will say on Sunday noon the third day of the month, A and B make their voyages in the same time, i. e. in twenty-four days, and return to the Greenwich meridian on Wednesday noon the twenty-seventh. But, during this interval of three weeks and three days A's reckoning shows a gain of one day, that is to say if he did not repeat a day he would apparently return to the Greenwich meridian on Thursday the twenty-eighth. During the same interval B's reckoning shows a loss of one day, and if he did not skip a day, he would apparently return to the meridian on Tuesday the twenty-sixth. Attention is called to the adjustments which are made on Friday the fifteenth. A's time, midnight Friday, is set back to midnight Thursday, or 0 Hr. A. M. Friday. B's time, midnight Thursday, or 0 Hr. A. M. Friday, is set forward to midnight Friday, or 12 Hrs. P. M. Friday. The travelers agree on the day of the week and month, but in their reckoning they differ by twenty-four hours, i. e. the difference between 0 Hr. A.M. and 12 Hrs. P. M. They make an exchange of apparent time.

On each of the subsequent days there is a diminution of two hours in their difference until the final adjustment on Wednesday noon the twenty-seventh when they return from opposite directions to the Greenwich meridian.

Greenwich Time			A's Time	B's Time
3	Sunday	Noon	Noon	Noon
4	Monday	Noon	1 P.M.	11 A.M.
5	Tuesday	Noon	2 P.M.	10 A.M.
6	Wednesday	Noon	3 P.M.	9 A.M.
7	Thursday	Noon	4 P.M.	8 A.M.
8	Friday	Noon	5 P.M.	7 A.M.
9	Saturday	Noon	6 P.M.	6 A.M.
10	Sunday	Noon	7 P.M.	5 A.M.
11	Monday	Noon	8 P.M.	4 A.M.
12	Tuesday	Noon	9 P.M.	3 A.M.
13	Wednesday	Noon	10 P.M.	2 A.M.
14	Thursday	Noon	11 P.M.	1 A.M.
{ 15	Friday	Noon	12 P.M.	0 A.M. }
{ 15	Friday	Noon	0 A.M.	12 P.M. }
16	Saturday	Noon	1 A.M.	11 P.M.
17	Sunday	Noon	2 A.M.	10 P.M.
18	Monday	Noon	3 A.M.	9 P.M.
19	Tuesday	Noon	4 A.M.	8 P.M.
20	Wednesday	Noon	5 A.M.	7 P.M.
21	Thursday	Noon	6 A.M.	6 P.M.
22	Friday	Noon	7 A.M.	5 P.M.
23	Saturday	Noon	8 A.M.	4 P.M.
24	Sunday	Noon	9 A.M.	3 P.M.
25	Monday	Noon	10 A.M.	2 P.M.
26	Tuesday	Noon	11 A.M.	1 P.M.
27	Wednesday	Noon	Noon	Noon

PLANET NOTES FOR JUNE, 1920.

The *sun* will continue its movement northward until June 22. At this time will occur the summer solstice, after which the sun will again slowly move southward. This is the month for the longest days and the shortest nights in the northern hemisphere.



THE CONSTELLATIONS AT 9:00 P. M., JUNE 1.

The phases of the *moon* for the month are as follows:

Full Moon	June 1 at	11:00 A.M.	C.S.T.
Last Quarter	9 "	1:00 P.M.	"
New Moon	16 "	8:00 A.M.	"
First Quarter	23 "	1:00 A.M.	"

The moon will be nearest the earth on June 16 and reach a point of maximum distance on June 2, and again on June 30.

Mercury, having passed the sun during the latter part of May, will continue to move eastward until June 29, when it reaches the point of greatest elongation east of the sun. At this date it will be at nearly the same declination as the sun, and will set nearly two hours after the sun. It should, therefore, be visible near the western horizon after sunset.

Venus will follow the sun eastward, gaining slowly upon it, and finally overtaking the sun early in July. It will, therefore, be too near the sun to be seen during this month.

Mars will cross the meridian at a very favorable time for observation during this month. It will cross the meridian on an average at eight o'clock in the evening. It will, however, be more than 9 degrees south of the equator so that its altitude will not be as great for northern observers as it sometimes is. On June 15 it will be about 70 million miles from the earth and receding from it.

Jupiter will be seen in the western sky at sunset during this month. At the beginning of the month it will cross the meridian shortly after 4:00 P.M., and at the end of the month, a little before 3:00 P.M. It will, therefore, be rather low at the end of twilight and will have passed its most favorable position for observation for this year.

Saturn will be about an hour and a half east of Jupiter. It may, therefore, be easily observed throughout this month.

Uranus will be in the southeastern sky in the early morning. It will cross the meridian at about 4:00 A.M.

Neptune will be in the same part of the sky as Jupiter and will, therefore, be rather low in the west in the early evening.

Occultations Visible in the United States, June, 1920

[NOTE:—Geographical positions are indicated by giving for each point, first the latitude, then the longitude, the two being separated by a hyphen. A line drawn on a map through the two or more points thus indicated will mark approximately the limit of the region of visibility for the United States.

The time given is the approximate Greenwich time of the middle of the occultation as seen from the United States.]

June 1, 14^h. 109 B. Ophi., Mag. 6.2 East of 30°-109°, 35°-105°, 37°-101°, and south of 37°-101°, 32°-88°, 26°-75°.

June 2, 0^h. ξ Ophi., Mag. 4.4. North of 37°-125°, 40°-117°, 43°-108°, and west of long. 100°.

June 2, 17^h. 16 G. Sagit., Mag. 6.4. East of 30°-132°, 40°-129°, 46°-121°, and south of 46°-121°, 40°-103°, 36°-89°, 34°-75°.

June 8, 22^h. 6 G. Pisc., Mag. 6.2. Throughout the U. S., but east of 50°-85°, 40°-75°, 30°-71°, occurs after sunrise.

June 9, 19^h. λ Pisc., Mag. 4.6. East of 25°-99°, 32°-100°, 39°-99°, and south of 39°-99°, 41°-81°, 47°-64°.

June 13, 0^h. 29 Arietis, Mag. 6.1. Southeast of 40°-127°, 46°-112°, and southwest of 46°-112°, 38°-101°, 28°-91°. (Farther east, occurs after sunrise.)

June 14, 0^h. 26 B. Tauri, Mag. 6.4. Southeast of 44°-127°, 47°-120°, and southwest of 47°-120°, 38°-104°, 28°-94°. (Farther east, occurs after sunrise.)

June 20, 12^h. 14 Sextant., Mag. 6.3. East of 25°-90°, 35°-84°, 45°-72°. (Farther west, occurs before sunset.)

June 20, 15h. 19 Sextant., Mag. 5.9. North of 50°-110°, 43°-94°, 40°-76°, and west of 40°-76, 45°-70°, 50°-66°.

June 23, 12h. χ Virg., Mag. 4.8. East of long. 85°. (Farther west, occurs before sunset.)

June 24, 9h. α Virg., Mag. 1.2. East of 30°-124°, 35°-122°, 40°-117°, and south of 40°-117°, 35°-95°, 28°-77°. (All before sunset.)

June 27, 17h. β Scorpii, Mag. 2.9. South of 44°-125°, 39°-108°, 40°-88°, 47°-66°.

June 27, 17h. 56 B. Scorpii, Mag. 6.4. South of 44°-125°, 39°-108°, 40°-88°, 47°-66°.

June 28, 23h. 109 B. Ophi., Mag. 6.2. Southeast of 32°-120°, 36°-111°, and west of 36°-111°, 32°-107°, 27°-104°.

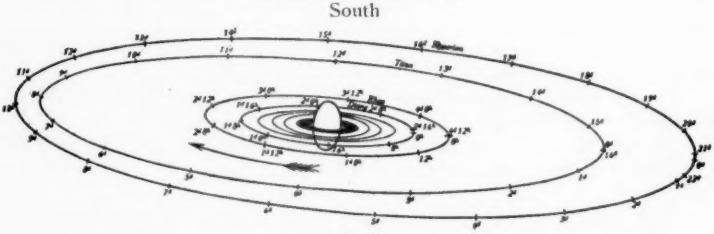
(An occultation of Mars, June 24, is visible in the south Pacific Ocean, including New Zealand.)

ARTHUR SNOW,
Ass't, Nautical Almanac Office, U. S. Naval Observatory.

Saturn's Satellites

[From the *American Ephemeris.*]

CENTRAL STANDARD TIME.



Apparent orbits of the seven inner Satellites of Saturn, at date of opposition, February 27, 1920, as seen in an inverting telescope, and elongated in the ratio of two to one in the direction of their minor axes.

E., Eastern Elongation. I., Inferior Conjunction (south of planet).
W., Western Elongation. S., Superior Conjunction (north of planet).

I. Mimas. Period 0d 22h.6.

1920	d	h		d	h		d	h		d	h
June	1	11.1 E	June	9	11.4 W	June	17	11.7 E	June	25	12.0 W
	2	9.7 E		10	10.0 W		18	10.3 E		26	10.6 W
	3	8.4 E		11	8.6 W		19	8.9 E		27	9.2 W
	8	12.8 W		12	7.3 W		20	7.6 E		28	7.9 W

II. Enceladus. Period 1d 8h.9.

June	2	3.0 E	June	8	23.5 E	June	15	22.0 E	June	22	16.5 E
	3	12.0 E		10	8.4 E		17	4.9 E		24	1.4 E
	4	20.8 E		11	17.3 E		18	13.8 E		25	10.3 E
	6	5.7 E		13	2.2 E		19	22.7 E		26	19.2 E
	7	14.6 E		14	11.1 E		21	7.6 E		28	4.1 E
										29	13.0 E

III. Tethys. Period 1d 21h.3.

June	1	23.0 E	June	9	12.2 E	June	17	1.6 E	June	24	14.8 E
	3	20.3 E		11	9.6 E		18	22.9 E		26	12.2 E
	5	17.6 E		13	6.9 E		20	20.2 E		28	9.5 E
	7	14.9 E		15	4.2 E		22	17.5 E		30	6.8 E

IV. Dione. Period $2^d\ 17^h.7$.

June	2	7.8 E	June	10	12.9 E	June	18	18.1 E	June	26	23.3 E
	5	1.5 E		13	6.7 E		21	11.8 E		29	17.0 E
	7	19.2 E		16	0.4 E		24	5.6 E			

V. Rhea. Period $4^d\ 12^h.5$.

June	4	0.9 E	June	13	1.8 E	June	22	2.9 E	June	26	15.4 E
	8	13.4 E		17	14.4 E						

VI. Titan. Period $15^d\ 23^h.3$.

June	5	7.4 E	June	13	2.3 W	June	21	7.1 E	June	29	2.2 W

VII. Hyperion. Period $21^d\ 7^h.6$.

June	5	11.3 W	June	16	18.9 E	June	26	16.8 W			

VIII. Iapetus. Period $79^d\ 22^h.1$.

						June	20	4.0 S			

IX. Phoebe. Period $523^d\ 15^h.6$.

	α Ph.—α Sat.		δ Ph.—δ Sat.			α Ph.—α Sat.		δ Ph.—δ Sat.	
	m	s	′	″		m	s	′	″
June 1	−0	44.8	+6	47	June 17	−1	02.7	+8	31
3	0	47.1	7	00	19	1	04.8	8	43
5	0	49.4	7	14	21	1	06.9	8	55
7	0	51.7	7	27	23	1	08.9	9	07
9	0	53.9	7	40	25	1	11.0	9	19
11	0	56.2	7	53	27	1	13.0	9	31
13	0	58.3	8	6	29	−1	14.9	+9	42
15	−1	00.5	+8	18					

VARIABLE STARS.

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time. To obtain Eastern standard time subtract 5^h; Central standard time 6^h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1920. June							
	h m	° ′		d h	d	h	d	h	d	h	d	h
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7	7	3						
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	2	0;	10	3;	18	6;	26	10
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	2	16;	10	9;	18	3;	25	21
RW Cassiop.	130.7	+57 15	8.9—11.0	14 19.2	3	7			18	3		
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5	5;	13	3;	21	2;	29	0
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	7	8;	15	3;	22	22		
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	7	3;	14	10;	21	17;	29	0
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	5				21			
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	2	18;	11	8;	19	22;	28	12
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	6	18;	17	21;	29	0		
RX Aurigae	4 54.5	+39 49	7.2— 8.1	11 15.0	1	18;	13	9;	25	0		
SX Aurigae	5 04.6	+42 02	8.0— 8.7	1 12.8	2	22;	10	14;	18	6;	25	22
SY Aurigae	05.5	+42 41	8.4— 9.5	10 03.3	10	3;	20	6;	30	9		
Y Aurigae	21.5	+42 21	8.6— 9.6	3 20.6	6	15;	14	8;	22	1;	29	18
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	6	12;	12	1;	23	2;	28	15
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	5	15;	13	4;	20	18;	28	8
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3			15	11				
RT Aurigae	23.0	+30 33	5.1— 6.0	3 17.5	6	5;	13	16;	21	3;	28	14
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	3	17;	10	22;	18	3;	25	8
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	4	14;	12	12;	20	10;	28	8
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	3	23;	14	3;	24	6		
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5					21	3		
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	4	16;	12	14;	20	13;	28	11
V Carinae	8 26.7	−59 47	7.4— 8.1	6 16.7	2	10;	9	3;	22	12;	29	5

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1920. June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
T Velorum	8 34.4	−47 01	7.6— 8.5	4 15.3	6 15;	15 21;	25 4					
V Velorum	9 19.2	−55 32	7.5— 8.2	4 08.9	2 9;	11 3;	19 21;	28 15				
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 00.0		10						
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	9 17;	16 12;	23 7					
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	1 12;	8 2;	21 7;	27 22				
S Muscae	12 07.4	−69 36	6.4— 7.3	9 15.8	8 9;	18 1;	27 11					
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	4 23;	12 23;	20 22;	28 21				
T Crucis	15.9	−61 44	6.8— 7.6	6 17.6	4 21;	11 14;	18 8;	25 2				
R Crucis	18.1	−61 04	6.8— 7.9	5 19.8	1 9;	7 5;	18 20;	24 16				
S Crucis	12 48.4	−57 53	6.5— 7.6	4 16.6	3 4;	12 13;	21 22;	26 15				
W Virginis	13 20.9	− 2 52	8.7—10.4	17 06.5	7 16		24 23					
SS Hydrae	25.0	−23 08	7.4— 8.1	8 4.8	3 5;	11 10;	19 15;	27 20				
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	5 4;	12 5;	19 5;	26 6				
ST Virginis	14 22.5	− 0 27	10.3—11.4	0 09.9	2 19;	10 24;	19 5;	27 10				
V Centauri	25.4	−56 27	6.4— 7.8	5 11.9	4 19;	10 7;	21 7;	26 19				
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	7 20;	15 9;	22 22;	30 11				
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	8 5;	15 15;	23 1;	30 11				
R Triang. Austr.	15 10.8	−66 08	6.7— 7.4	3 09.3	2 3;	8 22;	15 16;	29 6				
S Triang. Austr.	15 52.2	−63 29	6.4— 7.4	6 07.8	2 8;	8 16;	21 8;	29 15				
S Normae	16 10.6	−57 39	6.6— 7.6	9 18.1	4 9;	14 3;	23 21					
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	7 8;	16 5;	25 1					
RV Scorpii	16 51.8	−33 27	6.7— 7.4	6 01.5	6 13;	12 14;	24 17;	30 19				
X Sagittarii	17 41.3	−27 48	4.4— 5.0	7 00.3	4 9;	11 10;	18 10;	25 10				
Y Ophiuchi	47.3	− 6 07	6.1— 6.5	17 02.9		17 13						
W Sagittarii	17 58.6	−29 35	4.3— 5.1	7 14.3	5 12;	13 2;	20 16;	28 7				
Y Sagittarii	18 15.5	−18 54	5.4— 6.2	5 18.6	2 5;	8 0;	19 13;	25 7				
U Sagittarii	26.0	−19 12	6.5— 7.3	6 17.9	6 10;	13 3;	19 21;	26 15				
Y Scuti	32.6	− 8 27	8.7— 9.2	10 08.3	8 2;	18 10;	28 18					
Y Lyrae	34 2	+43 52	11.3—12.3	0 12.1	4 6;	10 7;	22 8;	28 9				
RZ Lyrae	18 39.9	+32 42	9.9—11.2	0 12.3	5 3;	11 6;	23 13;	29 16				
RT Scuti	18 44.1	−10 30	9.1— 9.7	0 11.9	5 7;	11 5;	23 3;	29 2				
κ Pavonis	18 46.6	−67 22	3.8— 5.2	9 02.2	8 10;	17 13;	26 15					
U Aquilae	19 24.0	− 7 15	6.2— 6.9	7 00.6	1 5;	7 5;	21 6;	28 7				
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	1 20;	8 20;	22 20;	29 20				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	7 12;	15 12;	23 12					
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	2 14;	10 7;	17 23;	25 16				
η Aquilae	47.4	+ 0 45	3.7— 4.5	7 04.2	1 6;	8 10;	22 18;	29 23				
S Sagittae	51.5	+16 22	5.6— 6.4	8 09.2	1 16;	10 1;	18 16;	26 19				
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	5 9;	11 16;	17 23;	24 8				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	3 18;	20 3						
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	1 0;	9 21;	18 18;	27 15				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	4 21;	11 14;	18 8;	25 1				
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	7 13;	14 7;	20 24;	27 17				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4		15 13		30 7				
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	1 14;	9 11;	17 7;	25 4				
SW Aquarii	10.2	− 0 20	9.9—10.8	0 11.0	7 14;	14 12;	21 9;	28 6				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	3 20;	13 13;	18 10;	28 3				
Y Lacertae	22 05.2	+50 33	9.1— 9.6	4 07.8	1 12;	10 4;	18 19;	27 11				
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	1 14;	12 8;	17 16;	28 10				
Z Lacertae	36.9	+56 18	8.2— 9.0	10 21.1	3 7;	14 4;	25 1					
RR Lacertae	37.5	+55 55	8.5— 9.2	6 10.1	2 1;	8 12;	21 8;	27 18				
V Lacertae	44.5	+55 48	8.5— 9.5	4 23.6	1 8;	6 8;	16 7;	26 6				
X Lacertae	22 45.0	+55 54	8.2— 8.6	5 10.7	2 5;	13 3;	18 13;	29 10				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	6 4;	11 15;	22 12;	27 22				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	2 15;	8 22;	21 12;	27 19				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	2 23;	15 3;	27 6					
V Cephei	23 51.7	+82 38	6.0—7.0	0 23.9	4 17;	13 17;	18 17;	25 16				

Minima of Variable Stars of Short Period.

[Calculated by members of the Class in General Astronomy in Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5h; Central Standard 6h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1920							
					June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8	2 4							
RT Sculptor.	31.5	−26 13	9.6—10.5	0 12.3	8 7;	15 23;	23 15;	31 7				
UU Androm.	38.5	+30 24	10.7—11.9	1 11.7	4 14;	12 1;	19 11;	26 21				
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	2 16;	10 3;	17 15;	25 2				
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	1 4;	7 7;	19 12;	25 15				
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	7 3;	14 6;	21 9;	28 13				
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	3 0;	9 21;	23 15;	30 11				
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	2 7;	9 11;	23 19;	30 23				
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	9 10;	18 5;	26 23					
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	7 23;	15 23;	23 21					
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6	11 17							
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	6 8;	12 0;	21 11;	29 4				
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	7 9;	14 4;	20 23;	27 19				
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	3 6;	11 4;	19 1;	26 23				
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	8 6;	16 13;	24 21					
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	5 20;	13 17;	21 15;	29 12				
RW Persei	13.3	+42 04	8.8—11.0	13 04.8		10 7;	23 12					
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	1 1;	10 11;	19 22;	29 8				
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	5 2;	17 12;	29 22					
TT Aurigae	5 02.8	+39 27	7.8— 8.7	0 16.0	1 16;	8 8;	21 16;	28 8				
RY Aurigae	11.5	+38 13	10.7—11.7	2 17.5	7 22;	16 3;	24 7					
RZ Aurigae	42.9	+31 40	10.6—13.3	3 00.3	2 1;	8 1;	20 2;	26 3				
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	3 18;	12 10;	21 2;	29 18				
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	3 22;	14 7;	24 17					
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	1 3;	9 3;	17 4;	25 4				
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	1 17;	7 11;	18 21;	24 15				
U Columbae	6 11.2	−33 03	9.2—10.0	2 19.2	1 10;	7 0;	18 5;	29 10				
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	5 9;	13 14;	21 19;	29 23				
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	7 23;	15 14;	23 5;	30 19				
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	11 2		23 7					
RU Monoc.	6 49.4	− 7 28	9.8—10.5	0 21.5	7 8;	14 12;	21 16;	28 20				
R Can. Maj.	7 14.9	−16 12	5.8— 6.4	1 03.3	2 5;	9 0;	22 16;	29 11				
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	3 14;	12 21;	22 4					
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	5 3;	11 18;	18 8;	24 23				
TX Gemin.	30.3	+17 8	10.0—11.9	2 19.2	1 15;	10 1;	18 10;	26 20				
RR Puppis	43.5	−41 08	9.4—10.7	6 10.3	4 20;	11 6;	24 3;	30 13				
V Puppis	7 55.4	−48 58	4.1— 4.8	1 10.9	6 16;	13 23;	21 5;	28 12				
X Carinae	8 29.1	−58 53	7.9— 8.7	0 13.0	7 5;	15 7;	23 10					
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	7 5;	16 17;	26 4					
RX Hydrae	9 00.8	− 7 52	9.1—10.5	2 6.8	6 5;	13 2;	19 22;	26 18				
S Velorum	29.4	−44 46	7.8— 9.3	5 22.4	3 16;	9 14;	21 11;	27 9				
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	2 18;	9 12;	22 23;	29 17				
RR Velorum	10 17.8	−41 36	10.0—10.9	1 20.5	3 15;	11 2;	18 12;	25 22				
SS Carinae	10 54.2	−61 23	12.2—12.8	3 07.2	2 10;	9 1;	22 5;	28 20				
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	3 10;	12 5;	21 0;	29 19				
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	6 23;	14 7;	21 15;	28 23				
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	5 6;	12 1;	18 20;	25 14				
RZ Centauri	12 55.6	−64 05	8.5— 8.9	1 21.0	6 13;	14 1;	21 13;	29 1				
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.1	9 0;	18 14;	28 4					
SS Centauri	13 07.2	−63 37	8.8—10.4	2 11.5	7 3;	14 14;	22 1;	29 11				
133926 Hydrae	13 39.0	−26 23	8.6—12.7	2 21.5	5 17;	11 12;	23 2;	28 21				
δ Librae	14 55.6	− 8 07	4.8— 6.2	2 07.9	6 7;	13 6;	20 6;	27 5				

Minima of Variable Stars of Short Period—Continued.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1920 June
	h m	° ′		d h	d h d h d h d h
U Coronae	15 14.1	+32 01	7.6— 8.7	3 10.9	2 16; 9 13; 23 9; 30 7
TW Draconis	32.4	+64 14	7.3— 8.9	2 19.3	8 19; 17 5; 25 15
SS Librae	15 43.4	−15 14	9.3—11.5	0 18.4	2 12; 10 4; 17 20; 25 12
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	2 6; 9 14; 16 22; 24 6
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5	4 13; 12 19; 21 1; 29 7
R Arae	31.1	−56 48	6.8— 7.9	4 10.2	1 4; 10 0; 18 21; 27 17
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	5 6; 14 23; 26 0
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	5 12; 12 7; 19 3; 25 22
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	5 18; 14 3; 22 12; 30 22
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	2 5; 8 9; 20 16; 26 20
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	5 10; 11 14; 17 18; 23 23
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	2 7; 9 16; 17 1; 24 10
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	3 8; 11 12; 19 16; 27 21
TX Scorpii	48.6	−34 13	7.5— 8.2	0 22.6	6 18; 14 6; 21 20; 29 9
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	4 1; 9 19; 19 12; 27 6
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	5 7; 13 7; 21 7; 29 6
WX Sagittae	53.6	−17 24	9.2—10.8	2 03.1	1 12; 10 1; 18 13; 27 2
WY Sagittae	17 54.9	−23 1	9.5—10.6	4 16.0	2 12; 11 20; 21 5; 30 13
SX Draconis	18 03.0	+ 58 23	9.3—10.5	5 04.1	1 13; 11 21; 22 6
RS Sagittarii	11.0	−34 08	5.9— 6.3	2 10.0	1 23; 9 5; 16 11; 23 17
V Serpentis	11.1	−15 34	9.5—11.1	3 10.9	7 13; 14 11; 21 9; 28 7
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2	8 5 23 8
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	5 21; 13 1; 20 5; 27 9
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	1 16; 8 18; 23 0; 30 3
SX Sagittarii	39.7	−30 36	8.7— 9.8	2 01.8	8 9; 6 17; 15 0; 23 8
RR Draconis	40.8	+62 34	9.3—13	2 19.9	3 8; 11 21; 20 7; 28 19
RS Scuti	43.7	−10 21	9.3—10.3	0 15.9	3 18; 10 10; 17 1; 23 17
β Lyrae	46.4	+33 15	3.4— 4.1	12 21.8	7 8; 20 6
U Scuti	18 48.9	−12 44	9.1— 9.6	0 22.9	7 13; 15 4; 22 19
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	5 11; 13 1; 20 15; 28 4
RV Lyrae	12.5	+32 15	11. —12.8	3 14.4	5 22; 13 3; 20 7; 27 12
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	1 18; 10 17; 19 16; 28 15
U Sagittae	14.4	+19 26	6.5— 9.0	3 09.1	2 13; 9 7; 22 19; 29 14
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	1 12; 8 21; 16 5; 23 14
TT Lyrae	24.3	+41 30	9.4—11.6	5 05.8	4 19; 10 1; 20 12; 25 18
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	1 20; 8 9; 21 10; 27 23
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	1 2; 7 2; 19 3; 25 3
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	2 18; 9 9; 22 16; 29 7
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	7 7; 16 10; 25 14
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	1 11; 9 22; 18 8; 26 18
RW Capric.	12.2	−17 59	8.8—10.6	3 09.4	3 10; 10 5; 23 18; 30 13
UW Cygni	19.6	+42 55	10.5—13	3 10.8	2 10; 9 7; 23 3; 30 0
V Vulpec.	32.3	+26 15	8.2— 9.8	37 19.0	19 14
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	9 6; 18 20; 28 11
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	7 18; 16 23; 26 3
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	6 3; 13 15; 21 3; 28 15
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	1 7; 8 22; 16 12; 24 2
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	3 5; 13 8; 23 10
VV Cygni	21 02.3	+45 23	12.1—13.8	1 11.4	1 4; 8 14; 23 8; 30 17
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	3 1; 12 18; 22 11
RY Aquarii	14.8	−11 14	8.8—10.4	1 23.2	2 15; 10 12; 18 8; 26 5
RT Lacertae	21 57.4	+43 24	9.1—10.5	5 01.7	2 4; 12 8; 22 11
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3	29 10
RW Lacertae	22 40.6	+49 08	10.2—11.2	5 04.4	2 16; 7 20; 18 5; 28 14
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.4	7 1; 15 8; 23 15
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.3	3 0; 10 13; 18 2; 25 14
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	3 5; 11 11; 19 17; 27 23

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers, Feb. 20-Mar. 20, 1920.

We report this month an encouraging increase in the number of observations at the end of an unusually severe winter. It is a pleasure to be able to acknowledge a splendid list from Mr. Bancroft who has been for a time somewhat incapacitated for active work by an unfortunate accident. Mr. Peltier and Mr. Lacchini are to be commended for valuable contributions. In the list of observations received this month from Messrs. Dawson and Tapia at La Plata, Argentina, there was no indication as to observer, and therefore these observations, which constitute an excellent list will be found recorded under the joint initials "δT." We welcome this month the maiden contribution of a new member, Mr. C. W. Gartlein, (Ga). Mr. McAteer writes that SS Cygni was bright on the morning of the 20th of March, and the observation will be included in the next report.

During the past few months the Council has elected to membership the following persons, who we hope will prove helpful additions to our ranks:

Allen Bassett	Chiengrai, Siam.
H. P. Broad	London, England
John Conner	Cleveland, Ohio.
Lincoln Ellsworth	New York, N. Y.
C. W. Gartlein	Connersville, Ind.
R. S. Gulden	New York, N. Y.
John Peters	East Holliston, Mass.
Louis Rayneld, S. J.	Santa Fe, Argentina.
George C. Waldo, Jr.	Fairfield, Conn.
Miss A. D. Walker	Quincey, Mass.

Two of our active members, Messrs. C. W. Elmer and S. L. Rhorer have become Life Members. Mr. Olcott, our Secretary, has had a very pleasant trip through the South and visited at the Leander-McCormick Observatory of the University of Virginia where he was entertained by Professor S. A. Mitchell. Rev. Bouton is intending to reside permanently at St. Petersburg, Fla., and we wish him the greatest happinesss is his new home, although we shall miss his cheery presence at our meetings.

The Memorial to Professor E. C. Pickering, so generously printed by Mr. Barns, of Morgan Hill, Cal., has been distributed and has been accorded high praise by all as a worthy tribute to our former leader and patron. A new edition of the Constitution has also been printed and distributed.

The place of holding the Spring meeting on the evening of May 8 has been changed to the Up-Town Club, at 11-17 West 45th St., New York City. A large attendance is assured, and it is hoped that as many members as possible will plan to be present at this gathering. During the summer it will be important for observers in whose communities day-light saving is adopted to be careful to reduce all observations to G.M.T. The Naval Observatory at Washington has requested our coöperation in securing observations of S Pyxidis *090024* to determine an accurate period. It is hoped that observers will keep this star on their active list.

Variable Star Observations, February 20 to March 20, 1920.

Feb. 0 = 2422355 Mar. 0 = 2422384

001032
S Sculptoris

J.D.	Est.	Obs.
242		
2262.7	8.3	δT
81.6	7.6	
88.6	7.4	
2313.7	6.9	
47.6	7.5	

001046
X Androm.

2384.5	11.6	M
90.5	<11.4	B

001620
T Ceti

2361.2	5.6	L

001726
T Androm.

2331.1	<11.0	Ch

001755
T Cassiop.

2365.4	7.7	L
80.3	8.7	
84.5	9.0	M
87.5	7.7	Ba
2400.6	9.4	Pt
02.6	7.9	Ba

001838
R Androm.

2332.1	9.2	Ch

001909
S Ceti

2331.1	10.5	Ch
61.3	10.3	L

002438a
T Sculptoris

2261.7	12.9	δT
81.6	13.4	
88.6	13.0	
2313.7	12.4	

002438b
RR Sculptoris

2313.7	12.7	δT

002546
T Phoenic.

2261.7	11.6	δT
81.6	13.3	
88.6	13.0	

003179
Y Cephei

2387.5	<12.0	Ba

004047
U Cassiop.

J.D.	Est.	Obs.
242		
2384.5	<11.7	M
93.6	11.3	Y
2401.6	10.8	Pt

004958
W Cassiop.

2384.5	11.0	M
87.5	10.2	Ba
2401.6	10.1	Pt
02.6	11.1	Ba

011208
S Piscium

2375.5	<12.5	Jk

011272
S Cassiop.

2384.5	8.8	M
87.5	7.9	Ba
2400.6	8.0	Pt

012350
RZ Persei

2387.6	10.2	Ba
93.6	10.4	Y

013238
RU Androm.

2333.2	<11.0	Ch
2401.6	11.1	Pt

013338
Y Androm.

2333.2	8.8	Ch
77.5	10.6	Pt
83.6	<11.2	B

014958
X Cassiop.

2375.6	10.9	Jk
84.5	<11.6	M
93.6	11.3	Y
96.6	<11.5	B

015354
U Persei

2377.6	9.2	Pt
84.5	9.0	M
85.6	9.2	B
87.6	8.4	Ba

021024
R Arietis

2361.3	11.7	L
78.3	10.6	
83.3	9.8	Pe
2401.5	9.2	Pt

021281
Z Cephei

242		
2397.6	<11.5	V

021403
ô Ceti

2337.2	8.9	Ch
57.3	8.9	L
62.3	9.2	Pe
67.3	9.1	L
69.8	9.3	Pe_2
72.6	9.0	Mu
75.6	9.1	
77.5	9.3	Pt
78.3	9.6	L
90.7	9.2	Mu

021558
S Persei

2387.6	9.4	Ba

022000
R Ceti

2362.3	8.8	Pe
69.8	8.4	Pe_2
83.3	8.7	Pe

022150
RR Persei

2391.5	11.0	Yo
93.6	10.2	Y

022813
U Ceti

2331.1	<11.0	Ch

022980
RR Cephei

2367.4	<13.0	L

023133
R Trianguli

2381.6	10.4	B

024356
W Persei

2377.6	10.0	Pt
91.7	10.7	

025050
R Horolog.

2261.7	12.6	δT
81.6	13.4	
88.6	12.9	
90.7	13.0	
2312.7	12.8	
45.6	12.8	
47.6	12.5	

025751
T Horolog.

2261.6	13.0	δT
81.6	13.2	
2300.6	13.1	
12.7	12.5	
45.6	10.3	
47.6	10.1	
53.6	9.8	

030514
U Arietis

2393.6	12.0	Y

031401
X Ceti

2366.4	9.2	L_2
77.5	9.0	Pt
78.3	9.3	L

032043
Y Persei

2370.3	10.1	Pe
77.6	10.2	Pt

032443
Nova Persei ≠2

2371.3	<12.3	Pe

034625
U Eridani

2281.6	8.7	δT
90.7	9.1	
2313.7	10.4	
47.6	12.2	

035124
T Eridani

2261.7	11.3	δT
81.6	12.0	
90.7	12.2	
2313.7	12.2	
45.6	10.7	
47.6	10.4	
53.6	10.2	

040725
W Eridani

2261.7	10.0	δT
81.6	9.7	
90.7	9.8	
2313.7	10.1	
45.7	11.3	
47.5	11.2	
53.6	11.5	

042209
R Tauri

J.D:	Est.	Obs.
242		
2377.6	10.7	Pt
78.4	10.8	Ja
90.6	11.8	B
93.5	<11.7	Pi

042215
W Tauri

2362.3	11.7	Pe
70.3	11.6	
78.3	12.2	Ja
91.5	12.1	Yo
97.6	<11.4	V
2402.6	11.4	Y

042309
S Tauri

2390.6	<12.0	B
93.5	<11.7	Pi

043065
T Camelop.

2378.7	9.1	L
87.6	8.8	Ba

043263
R Reticuli

2281.7	10.9	δT
90.7	10.6	
2312.7	11.4	
45.7	12.6	
53.7	<13.0	

043274
X Camelop.

2387.6	8.7	Ba
93.6	9.0	Y
97.6	9.1	B
2401.6	9.1	Pt
02.5	9.4	Ba

043562
R Doradus

2261.7	5.7	δT
81.7	5.5	
90.7	5.5	
2312.7	5.3	
45.7	5.2	
53.7	5.5	

043738
R Caeli

2261.7	9.4	δT
81.7	8.7	
90.7	8.3	
2312.7	8 7	
47.6	9.0	
53.6	8.9	

Variable Star Observations, February 20 to March 20, 1920—Continued.

044349
R Pictoris

J.D. 242	Est.	Obs.
2261.7	7.5	δT
81.7	8.3	
90.7	8.1	
2312.7	7.8	
47.6	7.3	
57.6	7.2	

044617
V Tauri

2379.3	10.1	Ja
92.5	9.5	Pi
93.6	9.7	B

045307
R Orionis

2393.6	11.9	Y
75.6	12.3	Jk

045514
R Leporis

2357.2	7.0	L
60.3	7.0	
65.4	7.2	
67.4	7.3	
78.3	7.2	
91.7	8.0	Pt
93.5	8.2	Pi
2401.5	7.6	Ya

050003
V Orionis

2393.6	<12.5	Y

050022
T Leporis

2377.5	8.2	Pt
93.6	9.2	Pi

050953
R Aurigae

2384.6	9.0	M
85.5	8.8	B
87.6	8.7	Ba
93.6	9.2	Pt
94.6	8.8	Ya
97.6	9.0	V

051247
T Pictoris

2261.7	9.3	δT
81.7	10.3	
90.7	11.2	
2312.7	13.2	
47.6	<13.4	
53.9	<13.9	

051533
T Columbae

J.D. 242	Est.	Obs.
2261.7	9.9	δT
81.7	8.4	
90.7	8.3	
2312.7	7.3	
47.6	7.3	

052034
S Aurigae

2360.2	9.6	L
83.6	8.2	B
85.4	9.2	Pe
92.5	9.1	Pi
94.6	8.7	Ya

052036
W Aurigae

2379.5	10.3	Ja

052404
S Orionis

2377.6	10.4	M
81.6	10.1	B
93.6	10.5	Pi
95.5	10.1	B

053005
T Orionis

2363.3	9.8	L
70.3	10.3	
70.3	10.6	Pe
77.6	10.0	M
77.6	9.9	Pt
80.8	10.1	L_2
81.6	9.9	B
93.6	9.7	Pi
95.5	10.0	B

053068
S Camelop.

2401.6	8.6	Pt

053326
RR Tauri

2379.4	11.3	Ja
90.6	11.8	B

053531
U Aurigae

2383.6	9.0	B
93.6	9.6	Y
94.6	9.3	Ya
97.6	9.4	V
2400.6	9.1	Pt

054319
SU Tauri

2337.5	9.5	Ba
60.2	9.7	L
61.2	9.8	

SU Tauri

J.D 242	Est.	Obs
2365.2	9.4	L
67.4	9.5	
79.4	9.0	Ja
87.5	9.4	Ba
92.5	9.4	Pi
93.6	9.4	B
93.6	9.8	Y
95.5	9.5	B
97.6	9.4	V
97.6	9.4	B
2402.5	9.4	Ba
02.6	9.7	Y

054615a
Z Tauri

2393.6	<12.7	Y

054615b
RS Tauri

2393.6	9.0	Y

054615c
RU Tauri

2393.6	<12.7	Y

054629
R Columbae

2261.7	13.0	δT
81.7	11.8	
90.7	10.7	
2312.7	9.9	
47.6	9.7	
53.6	9.4	

054920
U Orionis

2374.3	12.0	Pe
77.6	12.2	Pt
92.5	12.	Pi

054974
V Camelop.

2387.6	12.1	Ba
93.6	11.4	Y
2401.6	11.1	Pt
02.5	11.0	Ba

055353
Z Aurigae

2384.6	9.8	M
2402.6	10.5	Ya

055686
R Octantis

2347.5	<12.2	δT

060450
X Aurigae

2387.6	11.2	Ba
90.6	11.2	B
93.6	12.0	Pt

060547
SS Aurigae

J.D 242	Est.	Obs.
2337.5	<13.3	Ba
57.2	<11.5	L
60.2	<12.6	
61.2	<13.3	
63.2	<13.3	
65.2	<12.6	
67.2	<13.0	
70.4	<12.4	
73.5	10.9	Pr
74.5	11.2	
75.6	10.8	Jk
77.5	12.8	Pr
77.6	12.6	Pt
77.6	<12.4	M
78.2	<11.5	L
80.5	<13.3	E
87.6	<12.5	Ba
91.7	<12.6	Pt
93.6	<12.6	
93.6	<12.6	Y
95.5	14.0	Ba
97.7	<12.6	Pt
2400.6	<12.6	
01.6	<12.6	
02.5	<13.8	Ba

061702
V Monoc.

2393.6	<11.6	Pi

063159
U Lyncis

2393.6	12.6	Y
2402.6	12.5	

063308
R Monoc.

2393.6	11.5	B
93.6	<11.8	Pi

063558
S Lyncis

2387.6	10.6	Ba
2401.7	11.0	Pt
02.6	11.3	Ya

064030
X Gemin.

2397.6	7.7	V

065111
Y Monoc.

2392.5	10.8	Pi
93.6	10.8	Y

065208
X Monoc.

2360.3	7.5	L
70.3	7.4	
77.6	8.1	M

X Monoc.

J.D. 242	Est.	Obs.
2379.3	7.8	L
98.6	7.9	Ya

065355
R Lyncis

2387.6	9.3	Ba
93.6	9.3	Y
2402.6	9.3	

070122a
R Gemin.

2332.1	8.5	Ch
45.1	9.3	
80.4	10.4	Pe
2401.7	11.0	Pt

070122b
Z Gemin.

2380.4	<11.9	Pe
2401.7	12.3	Pt

070122c
TW Gemin.

2380.4	8.2	Pe

070310
R Can. Min.

2363.3	8.7	L
92.5	8.6	Pi
93.6	8.0	B

071713
V Gemin.

2401.7	8.9	Pt

072708
S Can. Min.

2374.4	<11.3	Pe
98.6	11.3	Ya
2402.5	12.0	Pi

072811
T Can. Min.

2401.5	11.9	Pt

073508
U Can. Min.

2393.6	11.9	Y
2400.6	11.5	Pt

073723
S Gemin.

2392.6	<12.4	Pi

074323
T Gemin.

2392.6	<11.5	Pi

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1920—Continued

074922
U Gemin.

J.D. 242	Est.	Obs.
2360.2	10.8	L
61.2	9.6	
62.3	9.4	
63.2	10.4	
65.2	11.7	
67.2	13.5	
70.3	<13.3	
75.6	<12.4	Yo
80.3	<12.4	L
87.5	<12.4	Ba
91.5	<13.3	Yo
92.6	<12.3	Pi
93.6	<13.3	Y
97.6	<11.7	V
98.5	<13.3	Yo
2401.7	<13.3	Pt
02.5	<13.8	Ba

081112
R Cancri

2319.2	9.3	Ch
39.1	8.5	
77.6	7.4	Pt
84.6	7.1	M
92.6	6.5	Pi
97.6	6.6	B
98.6	6.5	Ya
98.6	7.1	Yo

081617
V Cancri

2379.5	12.1	Ja
92.9	12.2	Pi
98.6	12.6	Yo
2402.6	10.8	Ya

082405
RT Hydrae

2363.3	8.3	L
97.6	7.8	B

083019
U Cancri

2397.6	12.6	B
2400.6	<11.6	V

083350
X Urs. Maj.

2387.6	<12.4	Ba

084803
S Hydrae

2319.2	9.6	Ch
39.1	8.0	
97.6	8.1	B
2400.6	8.0	Pt
02.6	8.3	Pi
02.6	8.4	Ya

085008
T Hydrae

2319.2	8.3	Ch
63 3	9.9	L
77.6	10.9	Pt

085120
T Cancri

2363.3	9.2	L
79.3	9.2	

090151
V Urs. Maj.

2362.3	10.4	Pe
81.6	10.4	B

090425
W Cancri

2363.3	12.6	L
79.3	13.0	
98.6	<12.6	Yo

091868
RW Carinae

2261.7	<13.0	δT
2300.7	<12.8	
47.6	11.8	
49.6	11.8	

092962
R Carinae

2261.7	4.6	δT
81.7	5.4	
2300.7	6.0	
47.6	8.6	

093178
Y Draconis

2387.6	<12.2	Ba
93.6	13.4	Y

093934
R Leo. Min.

2365.4	6.5	L
77.6	7.0	Pt
79.3	6.6	L
84.6	7.0	M
96.6	6.7	B
98.6	7.0	Ya
2402.6	7.3	Pi

094211
R Leonis

2319.2	9.8	Ch
37.2	9.2	
62.3	7.4	Pe
72.0	7.2	Pe_3
77.6	6.6	M
81.6	6.5	B
81.9	7.0	Pe_2
91.6	6.5	Yo
93.6	6.1	Pt

R Leonis

2398.5	6.2	Su
98.6	6.2	Ya
2442.6	6.5	Pi

094262
l Carinae

2261.7	3.6	δT
81.7	4.2	
90.7	3.5	
2312.7	4.0	
47.6	3.7	

095421
V Leonis

2402.6	<12.8	Pi

100661
S Carinae

2261.7	6.3	δT
81.7	7.7	
2347.6	6.1	
49.6	6.3	

103212
U Hydrae

2365.4	5.2	L
84.6	5.1	

103769
R Urs. Maj.

2322.4	8.5	Ch
37.2	7.4	
69.3	6.9	Pe
77.6	7.6	M
77.6	7.5	Pt
87.6	7.9	Ba
92.1	7.8	Ga_2
2402.7	8.0	Ya

104620
V Hydrae

2370.4	6.6	L
84.6	7.3	

104814
W Leonis

2393.6	11.4	Y
97.6	11.8	B
2400.6	<11.2	V

114441
X Centauri

2261.7	11.5	δT
81.7	12.	
2347.6	12.2	
49.6	12.3	

115919
R Com. Ber.

2379.5	13.2	Ja

122001
SS Virginis

2370.4	7.3	L
78.7	7.8	

122532
T Can. Ven.

2384.6	10.2	M

123160
T Urs. Maj.

2369.3	<12.4	Pe
75.5	12.4	Jk
87.6	<12.0	Ba

123307
R Virginis

2365.4	8.0	L
84.4	10.1	Pe
84.6	10.4	L
93.6	11.0	Pt

123459
RS Urs. Maj.

2371.7	11.0	Pe_3
77.7	10.2	M
80.3	10.3	Pe
87.6	9.0	Ba
93.6	8.9	Pt

123961
S Urs. Maj.

2365.3	11.2	L
70.4	10.6	Pe_2
75.5	10.3	Jk
77.7	9.9	M
78.3	10.1	L
80.3	9.9	Pe
87.6	9.2	Ba
93.6	9.2	Pt
2400.6	9.0	V

124606
U Virginis

2393.7	9.0	Pt
81.6	9.6	Ja_2

132422
R Hydrae

2378.7	8.8	L
97.7	9.0	Pt

132706
S Virginis

2379.6	7.7	Ja
97.7	7.8	Pt

133273
T Urs. Min.

2387.6	11.3	Ba

133633
T Centauri

2347.6	6.3	δT
49.6	6.2	

134440
R Can. Ven.

2393.6	11.1	Pt
93.6	10.8	Y

140113
Z Bootis

2402.6	<13.4	Y

140512
Z Virginis

2383.6	12.9	Ja
97.8	12.9	Pt

141567
U Urs. Min.

2387.6	10.9	Ba

141954
S Bootis

2365.4	11.0	L
78.3	10.6	
87.6	10.1	Ba
2401.7	9.4	Pt
02.6	9.0	Y

142539
V Bootis

2365.4	7.7	L
93.6	8.1	Pt

142584
R Camelop.

2402.5	8.3	Ba

143227
R Bootis

2393.6	7.3	Pt
98.6	7.0	Su

145254
Y Lupi

2349.6	13.1	δT

151432
V Cor. Bor.

2322.4	7.5	Ch

151520
S Librae

2351.4	9.5	Ch
84.7	8.8	L

151731
S Cor. Bor.

2322.4	7.7	Ch
97.7	9.6	Pt
2402.6	8.9	Y

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1920—Continued.

151822
RS Librae
J.D. Est.Obs.
2384.7 11.1 L

153378
S Urs. Min.
2402.5 11.1 Ba

154428
R Cor. Bor.
2370.4 6.0 L
72.4 6.1 Pe
78.6 6.1 L
79.6 6.2 Ja
84.6 6.2 L
90 9 6.1 E
94.7 6.3 Mu
96.7 6.3
97.7 6.1 Pt
98.7 6.8 Su
2400.6 6.0 Pt
01.7 6.2

154615
R Serpentis
2381.6 6.2 Ja_2
97.7 6.8 Pt

160210
U Serpentis
2397.7 10.0 Pt

161122a
R Scorpii
2383.6 12.6 Ja
97.8 12.9 Pt

161122b
S Scorpii
2383.6<13.0 Ja
97.8 12.6 Pt

161607
W Ophiuchi
2384.7<13.0 L

162119
U Herculis
2323.4 9.7 Ch
97.7 11.1 Pt

163137
W Herculis
2323.4 8.5 Ch
97.8 9.9 Pt

163172
R Urs. Min.
2402.6 10.1 Ba

163266
R Draconis
J.D. Est.Obs.
2375.5 10.4 Jk
2402.6 7.9 Ba
02.6 8.0 Y

165631
RV Herculis
2397.8 10.6 Pt

170215
R Ophiuchi
2351.4<11.0 Ch

171401
Z Ophiuchi
2383.7 8.9 Ja
97.8 8.4 Pt

171723
RS Herculis
2397.8 12.0 Pt

175458a
T Draconis
2402.6 10.1 Y

175458b
UY Draconis
2402.6 11.6 Y

180531
T Herculis
2351.4 8.2 Ch
78.7 7.7 L
97.8 9.1 Pt

180565
W Draconis
2375.6 11.7 Jk

180911
Nova Ophiu. #4
2378.7 10.4 L

181136
W Lyrae
2397.8 11.8 Pt

184205
R Scuti
2378.7 7.3 L
83.7 6.3 Ja
84.7 6.7 L
97.8 5.5 Pt

184300
Nova Aquilae #3
2378.7 8.2 L
83.7 8.4 Ja
97.8 8.1 Pt

191033
RY Sagittarii
J.D. Est.Obs.
2375.6 6.8 δT
81.6 6.7

191637
U Lyrae
2390.9 10.0 E
97.8 10.7 Pt

193449
R Cygni
2327.1 8.0 Ch
38.0 8.2
90.9 9.2 E
97.8 9.7 Pt

194048
RT Cygni
2327.1 7.8 Ch
38.0 7.6
90.9 9.0 E
97.8 9.2 Pt

194348
TU Cygni
2390.9 10.1 E
97.8 10.6 Pt

200938
RS Cygni
2360.3 9.0 L
84.7 8.6
97.8 8.9 Pt

201139
RT Sagittarii
2275.6 10.7 δT

201647
U Cygni
2397.8 10.6 Pt

202946
SZ Cygni
2337.5 9.3 Ba

202954
ST Cygni
2375.5 12.3 Jk

204405
T Aquarii
2331.0 11.0 Ch

210868
T Cephei
2365.4 6.8 L
80.3 6.5
2402.6 5.7 Ba

212030
S Micros.
J.D. Est.Obs.
2275.6 10.0 δT
77.6 9.9
81.6 10.1

213244
W Cygni
2357.2 5.7 L
60.3 5.4
65.3 5.7
80.8 5.6 L_2

213678
S Cephei
2402.6 8.0 Ba

213843
SS Cygni
2329.0<11.0 Ch
32.0 8.3
33.1 8.5
37.1 8.6
37.5 8.4 Ba
40.1 8.7 Ch
42.1 8.8
43.1 9.0
45.1 9.4
57.2 11.6 L
60.3 11.3
61.3 11.7
63.3 11.5
65.3 11.7
67.3 11.4
70.3 11.5
77.5 11.7 Pt
78.3 11.6 L
80.3<11.3
80.9<10.9 E
83.3<10.4 L
84.7 11.7
90.9<10.9 E
94.9<10.9
97.8 11.6 Pt

221948
S Gruis
2275.6 11.6 δT
77.6 11.6
81.6 11.7
88.6 11.9

222439
S Lacertae
2363.3<12.4 L

223841
R Lacertae
J.D. Est.Obs.
2362.3 10.0 L
80.3 11.0

230759
V Cassiop.
2369.3 8.7 Pe
2400.6 7.3 Pt
02.6 7.0 Ba

231425
W Pegasi
2363.3 9.4 L
78.3 8.7

232746
V Phoenicis
2275.6 12.2 δT
77.6 12.1
81.6 12.1
88.6 10.9

233335
ST Androm.
2333.1 9.5 Ch
77.5 8.8 Pt

233815
R Aquarii
2331.0 6.9 Ch
43.1 7.6

233956
Z Cassiop.
2402.6<12.1 Ba

235150
R Phoenicis
2277.6 9.1 δT
81.6 9.0
88.6 9.0

235209
V Ceti
2361.3 11.4 L

235855
Y Cassiop.
2402.6<12.1 Ba

235939
SV Androm.
2375.6 11.0 Jk
77.5 10.9 Pt
2402.6 11.6 Y

No. of Observations: 636. No. of Stars Observed: 193. No. of Observers: 21.

The following members contributed to this report: Messrs. Bancroft, Bouton, Chandra, Dawson, Eaton, Gartlein, Janczewski, Lacchini, McAteer, Mundt, Peltier, de Perrot, Pickering, Suter, Tapia, Vrooman, Yalden and Yont; and Misses Jenkins, Parsons and Young.

HOWARD O. EATON, Recording Secretary.

American Association of Variable Star Observers.—At the invitation of Mr. David B. Pickering, the next meeting of the Association will be held at the "Uptown Club", 11-17 West 45th Street, New York City, (between 5th Avenue and Madison Avenue), on Saturday, May 8, 1920. The Council will meet at 5 o'clock in the afternoon, and the general business meeting will be called at 8 o'clock in the evening.

A large attendance is already assured, and it is hoped that all who can will add to the success of the meeting by their presence. Those who expect to be present will please notify Mr. Pickering, 171 South Burnett Street, East Orange, New Jersey, at their earliest convenience.

Reports of Committees, reading of papers, and a general discussion of our variable star work promise to be of exceptional interest to one and all. If you have any notes or suggestions to offer, please bring or send them, in order that they may receive due consideration.

LEON CAMPBELL, President.
WILLIAM TYLER OLCOTT, Secretary.

Six New Variable Stars.—In Circular 221 of Harvard College Observatory Miss Annie J. Cannon gives a list of 26 stars having peculiar spectra. Of several of them it is remarked that they change from one type of spectrum to another in the course of their variation. Six are new variables, their positions for 1900.0 being as follows:

DM	R.A.1900.0	Dec.1900.0	Magnitude	Period
°	h m	° ′		
+22 1109	5 51.0	+22 50	9.5 — 10.1	
. . .	7 00.9	—75 50	10.5 — 12.5	Irregular
—10 2171	7 37.5	—10 39	10.0 — 10.7	
. . .	17 34.4	—32 10	7.8 — 8.7	
. . .	19 43.7	+ 3 27	10.5 — 11.6	
. . .	20 09.6	+ 4 30	10.2 — <12.0	Long

A Long Period Variable.—The star T Pyxidis, R. A. $9^h\ 0^m\ 32^s$, Dec. $-31°\ 58'.7$ (1900), was discovered by Miss Leavitt on photographs made in 1902. See H. C. 179. Its magnitude at that time was 7.4. At first, it was thought to be a nova. Not until an examination had been made of four hundred photographs of the region was it again found bright on a photograph made in 1890. Between these dates it was of about the fourteenth magnitude. These observations indicated a period of twelve years, and in 1914 a careful investigation was made, but apparently no maximum occurred. Recently, Miss Woods, while engaged in the systematic search for novae, again found this star at maximum, after an interval of eighteen years. These three maxima, 1890, 1902, and 1920, are all that have been found, although an extended search has been made. From a photograph obtained last night the star appears to have the early form of nova spectrum. Its magnitude at the present time is about 7.

Harvard College Observatory Bulletin 716. S. I. BAILEY.
Cambridge, Mass., U. S. A., April 9, 1920.

COMET AND ASTEROID NOTES.

An Observation of Holmes' Comet?—From *The Observatory* for February, 1920, we learn that Dr. Baade, of Hamburg, on December 10 photographed a nebulous object on two plates, its R.A. being $21^h\ 42^m\ 00^s$, and its declination south 5° 54′.1; hourly motion $+3^s.8$, north 7″. The object is possibly Holmes' comet, which was due at perihelion on November 30. A later statement is that the motion does not agree with that of Holmes' comet.

Asteroid (99) Dike.—On March 29 a cablegram was received at Harvard College Observatory from Professor Lecointe, at Uccle, Belgium, announcing the discovery of a planet by Solá, of Barcelona, in the following position:

March 21.4975 G.M.T. R.A. $12^h\ 25^m\ 12^s.0$; Dec. + 15°,
Daily motion, R.A. -1^m; Dec. + 1′.

This turns out to be the planet (99) Dike, for which the ephemeris published in the Berlin Jahrbuch requires a large correction: about $+11^m$ in R.A. and about $-1°\ 50'$ in Dec. Its magnitude at opposition appears to be about 11.5 instead of 12.9 as given in the Jahrbuch.

GENERAL NOTES.

Dr. John A. Brashear, known and loved by all American astronomers, died on April 8, 1920, of congestion of the lungs. He was in his eightieth year.

Miss Jessica M. Young, instructor in astronomy at Northwestern University during the first semester, has been instructor in mathematics and astronomy since the beginning of the second semester of this college year.

Professor E. W. Brown, of Yale University, whose term of office as representative of the American Mathematical Society on the Division of Physical Science in the National Research Council would have expired this month, resigned in December. The Council of the Society appointed as his successor Professor Oswald Veblen of Princeton University.—(The *American Mathematical Monthly*, April, 1920.)

Professor O. M. Leland, of Cornell University, has taken a position with the J. G. White Engineering Corporation in New York. He has been at Cornell since 1903, and has had charge of the departments of Topographic and Geodetic Engineering and Astronomy. He served in the war as Lieutenant Colonel of Engineers in the St. Mihiel and Argonne-Meuse campaigns and later in Germany with the Army of Occupation.

Stars Having Composite Spectra.—In Circular 221 of Harvard College Observatory, Miss Annie J. Cannon gives a list of 116 stars having composite spectra. Seventy-three of these are new double stars.

Parallax of Krueger 60.—In the *Astronomical Journal* No. 767 Professor S. A. Mitchell gives the parallaxes of the components of the double star Krueger 60 and the faint star near by, from photographs taken at the Leander McCormick Observatory during the years 1916-1918. The resulting parallaxes from 21 plates are

For star A $\pi = 0''.267 \pm 0''.011$
B $\pi = 0\ .265 \pm 0\ .014$
C $\pi = 0\ .001 \pm 0\ .010$

The pair AB form a binary system with a period of about 50 years. The companion star C evidently does not belong to the system, since its distance is enormously greater.

The masses of A and B are approximately two-sevenths and one-seventh of that of the sun. The luminosity of B is only $1/2500$ that of the sun although its mass is one-seventh, so that it is intrinsically one of the faintest stars known.

The Henry Draper Catalogue.—Volume 94 of the Annals of the Harvard College Observatory contains the fourth installment of the Henry Draper Catalogue of the spectra of stars. This installment covers the hours 9, 10 and 11 of right ascension. The serial numbers of the stars run from 77801 to 104953. The Frontispiece of this volume is a reproduction of an admirable portrait of Professor Edward C. Pickering, who was for forty-two years director of Harvard College Observatory, and whose death occurred on February 3, 1919.

The South American Observing Station of the Smithsonian Astrophysical Observatory, located at Calama, Chile, will be taken over by the meteorological service of Argentina, if tentative arrangements already made to this end are approved by the Argentine Government. This transfer would set free funds of the Smithsonian Institution for a solar station in Egypt. (*Scientific American*, April 17, 1920.)

Franklin-Adams Chart of the Sky.—The Royal Astronomical Society has undertaken the publication of a second edition of this important photographic chart, which covers the whole sky in 206 sheets and shows stars down to the 16th or 17th magnitudes. The set of charts will be sold at 20 pounds. Subscriptions should be sent to the assistant secretary of the Royal Astronomical Society, Burlington House, W., London.

Gregorian Calendar Adopted in Roumania.— According to *L'Astronomie*, December 1919, the Gregorian Calendar was adopted in Roumania by decree of March, 1919. The change became effective April 1, 1919 (old style), that date becoming April 14, 1919. The church continues to use the Julian Calendar.

Weather Forecasting from "Solar Constant" Measurements.— In a recent lecture before the Washington Academy of Sciences, Director C. G. Abbot, of the Smithsonian Astrophysical Observatory, described the use that is being made of "solar constant" observations by the meteorological service of Argentina as a basis of weather forecasts. The head of the Argentina forecasting service, Mr. H. H. Clayton, aftetr an extensive comparison of weather records

in Argentina and the solar observations at Mount Wilson, announced that he had found evidence of a very marked influence of abnormal solar constant values upon both temperature and precipitation. The effects follow by some days the times of maximum and minimum radiation. In July, 1918, the Smithsonian Institution established a new station for solar observation at Calama, Chile, and ever since December, 1918, a daily code telegram has been sent from Calama to Buenos Aires stating the intensity of solar radiation outside the atmosphere. One curious fact revealed by this undertaking is stated to be that the dependence between solar variations and changes of temperature at Buenos Aires occur in opposite senses at different seasons of the year. From October to February low values of solar radiation are followed for several days by negative temperature departures from the normal, while the reverse is true from March to September. Occasional exceptions to this rule are recorded. Dr. Abbot thinks that this new auxiliary in forecasting is so promising as to justify the expense of establishing additional solar constant stations in other regions of the world favored with clear skies. *(Scientific American,* April 10, 1920.)

The Liberty Calendar.—The American Equal Month Calendar Association, with headquarters at the Oneida Building, Minneapolis, Minnesota, is sending out a postcard folder advocating what it calls the "Liberty Calendar", in which the year is divided into 13 equal months of 28 days each. This accounts for 364 days of the year, the days of the week having the same numbers in all the months. The extra (365th) day in ordinary years is New Year Day, a legal holiday with no week day name or number in the month. The additional day in Leap Year is also a legal holiday placed between June and July and is not included in any week or month.

The new month is called Liberty and is placed between February and March. There are four months in summer and three in each of the other seasons. Liberty is the first month of spring.

This is the simplest of all the plans which have been proposed for the reform of the calendar, and it would seem as if there might be some chance of its adoption.

In order to retain one-seventh of the time for Sundays, it is proposed that each seventh New Year Day become "New Year Sunday", and each seventh Leap Year Day become "Leap Year Sunday".

In every month the 1st, 8th, 15th and 22nd are always Monday, the 2nd, 9th, 16th, 23rd, always Tuesday, the 3rd, 10th, 17th, 24th, always Wednesday, etc. One would always know the day of the month as easily as he now knows the day of the week.

Good Friday and Easter Sunday are set on certain fixed dates, rendering unnecessary the use of complicated computations and tables for determining these dates. The Fourth of July, Armistice Day, Thanksgiving Day, and Christmas, would all come on Thursday every year. Oddly enough the Declaration of Independence was signed on Thursday.

It is suggested that this simplified calendar could be adopted to take effect, and with scarcely any friction whatever, on Sunday the first day of the year 1922.

A bill has already been introduced in Congress and those interested are asked to write their Congressmen to favor it.

Wireless Signals to Mars.—Is it possible to send wireless signals to Mars, the reader will doubtless inquire. The outlook is rather discouraging. We cannot yet send wireless signals half-way round the earth, and if we could, the reason for it might be in the fact, as many able scientists declare, that the solid earth transmits the signals more than the ether. But waiving this difficulty, from half-way round the earth, or 12,000 miles, to the 35,000,000 to Mars when it is nearest, is a rather big jump, 3,000 times as big as our biggest and more, because Mars comes as near to us as that only once in 15 or 17 years, and that for a few days only, its nearest distance this year being 54,000,000 miles. The power to transmit a signal through space to such a distance would really be stupendous. If a lightning flash on earth is believed to carry the energy of millions of horsepower, will anyone maintain that such a flash could be seen from Mars, and if not seen, how much less perceived in any other way?

But granting even this possibility, it will be a long operation for earth and Mars to understand one another's signals. Dots and dashes form letters and words and sentences for us, but they are in a known language. What language do the Martians speak?

Suppose that after the great excitement of the established intercourse has abated, we at last do understand one another, what shall we talk about? Shall we tell Mars of our history, of our inventions, and of our politics? only to hear its equally useless gossip in return? And lastly, who will pay for all this fun? Of what earthly use will it be to us?

All this takes for granted, of course, that there are as a fact intelligent beings on Mars, and this fact is very questionable. We know that the average temperature on Mars must be very low, probably 30 below zero, because it gets less than half as much heat from the sun as the earth does. How, then, can anything grow? Of course, we may imagine beings living on ice, or even in fire, if we like, but this Mars will belong to a different nature from the one we know on earth, and all our reasoning and deductions from our terrestrial knowledge and experience are inapplicable and we are worse off than ever. The knowledge we have teaches us most emphatically that the earth is the only planet fit to live on, materially at least, if not politically, and by all means spiritually, because the earth was and is honored by the Son of God Himself in His human and in His divine nature. That there may be other planets inhabited by intelligent beings is possible, of course, but it is certainly not the case in our solar system. Whether other suns have planets and inhabited ones will never be known by mortal men on this earth. In heaven, of course, we shall know all that we shall like to know, but eternal ignorance and deceit is the portion of the nether regions.

Newspapers have often stated that Prof. Todd intended to go up very high in a balloon in order to observe Mars to better advantage. No one has yet ascended to the height of 10 miles and no one will ever go as high as 100 or 1,000 and even if he did, what is a thousand miles in the 35,000,000 to Mars? I do not believe that Todd has any such childish notions. Even the purity and rarity of the air at great heights could not be used to advantage in a telescope on a balloon. Nowadays all astronomical work of that kind is photographic, and requires large and elaborate instruments firmly mounted and delicately adjusted. And even if this difficulty could be met, what is the use of such a balloon ascension when the hundred or the thousand miles it would take us nearer to Mars could be gained more conveniently by making use of our knowledge of the

motions and positions of the earth and Mars in their orbits, in which such paltry distances would be of as much account as leaning forward in our arm chair in order to get a better look at the moon.—(WILLIAM F. RIGGE, in *The Bee*, Omaha, Neb., April 19, 1920.)

The Auroral Displays of March 22 and 24, 1920.—In the April number of POPULAR ASTRONOMY Mr. Lewis J. Boss of North Scituate, Rhode Island, gave an account of the remarkable auroral display, which appears to have been visible in all parts, at least the northern parts, of the United States. At Northfield the display was very brilliant and covered almost the entire sky at times, but we took no notes concerning the phenomena.

The following are some of the descriptions which have been sent in of the auroras of March 22 and 24 as seen at various stations:

ANN ARBOR, MICH.—On Monday, March 22, at nightfall features of an unusually remarkable aurora became visible at Ann Arbor. Brief notes concerning the phenomena observed on this occasion and also two nights later may be of interest especially for comparison with records made elsewhere.

The aurora of March 22, as seen from Ann Arbor, was notable particularly for its extension over nearly the entire sky. Though active streamers and other features often centered in and toward the north and were delimited below by a marked black arch, at times perhaps the northern third or more of the sky was nearly devoid of visible auroral light while most of the rest of the heavens was illuminated. A well defined *southern* black arch was seen at intervals, having a meridian altitude of perhaps twenty or thirty degrees. When last observed, (about two A. M.), there was no auroral light in the northern half of the sky. The southern black arch was well defined and above it was first a green arch and still higher a stronger one distinctly yellow in color.

At about ten P. M. an auroral curtain answering well to descriptions of such displays as witnessed in polar regions was observed in the southeast for about ten minutes. This curtain was centered at an altitude of about sixty degrees and extended some thirty degrees right and left, with folds in an apparently vertical direction about ten degrees long. Shortly before this curtain appeared the light in the southeast was strong enough to cast a noticeable shadow.

A striking feature of the display was the convergence of many of the streamers that marked the phenomenon toward a well defined point about fifteen degrees south of the zenith. This convergent, or radiant, continued sensibly in this position, when well brought out, during the first half of the night and probably longer.

During the observations there were no pronounced color displays of long duration aside from that of the auroral green. A striking purple vertical streamer was seen at about 7:15 P. M. in the northwest, and again the flocculent luminous patches of green toward the east and west were flashed with red as clouds are occasionally at sunset. The yellow southern arch is mentioned above. On the following night no notable auroral phenomena were observed.

On the night of March 24, a cloudy sky cleared for half an hour shortly after eleven P. M. Little or no auroral light was visible in the north. Almost due south an oval patch of green light of variable intensity was observed at about twenty degrees altitude—about eight degrees across vertically and twenty degrees horizontally. At times this light was quite strong. Two other variable

patches, one each in the southeast and southwest, were also visible somewhat nearer the horizon than the first and at times connected with it by faint streamers, the whole forming the central part of a flat arch, brightest and heaviest at the top. The observer noted no change of position in the features described, while walking a mile in a southwesterly direction.

It is of course well known that a great sun-spot group, more than 200,000 miles long the next day, was not far from the apparent center of the sun on the night of March 22.

R. H. CURTISS.

DETROIT, MICHIGAN.—On March 22, 1920, we had an extremely brilliant auroral display. This had been fairly bright on the northern horizon throughout the early evening. About 9:50 (Eastern Standard Time) an arch approximately 9° wide appeared across the heavens from the northwest about 10° south of Jupiter, 12° south of Regulus, through Spica to the horizon a little east of where Mars had just risen. It seemed to be fairly uniform in width, but very irregular. This changed to a cone of light that stretched from the horizon on all sides to the apex, exactly in the radiant of the Leonids. At this phase it was so brilliant as to blot out all stars below the first magnitude. The colors were pale, except for a pronounced ruddy color south of Jupiter and Saturn. The light subsided but rose again to the same apex though the stars had moved on (was this a coincidence?). The light was brightest in the south and southeast, but covered the whole sky. It occurred in spasmodic outbursts of brilliancy until daylight.

W. B. KENNEDY.

ANN ARBOR, MICHIGAN.—At about 7:00 P. M. C. S. T., on March 22, I was photographing the crescent moon with my smaller telescope mounted on the tube of the larger, the latter being used as guiding telescope. The exposure was about 10 minutes, as I wished to get the ashy light in the picture.

While guiding, I noticed a few streaks in the western sky, but thought they were wisps of cloud. However, when the exposure was finished, I soon became aware of their auroral nature. Then an auroral haze appeared, stretching along the equinoctial, from the horizon through Orion. Brighter streamers now began to shoot up from the northern, eastern and western horizon and the flickering became noticeable. Until about 7:30, no color was seen, but the streamers then began to take on a light green tint which became more and more pronounced. The green was especially noticeable in the northeast where the aurora took the form of a beautiful curtain hanging down to within about twenty degrees of the horizon at the north, arching upward to Mizar and downward to Arcturus.

Several times it appeared as if the display were coming to an end, but each time it began again, more vigorously than before. By 8:30 it covered practically the entire sky, the streamers flashing up from the entire circumference of the horizon and meeting, in general, at a point about 20° south of the zenith. (The dip of the needle at Ann Arbor is 73°; or 17° from the zenith). I will call this point the "radiant" for convenience. The haze in Orion had disappeared entirely by this time.

At about 9 o'clock, the streamers began to flash more vigorously and they grew brighter momentarily. Suddenly, there was a veritable explosion. Like flashes of lightning, the east and west streamers shot up, glowing brilliant green and rivalling the electric street lights. A great double arch formed in the space of a minute or so. It stretched from west to east through the radiant. It was brilliant green with pale red borders and flashed like flame. In about five min-

PLATE XIII

Toward East at 8:55 C.S.T.,
exposure 5^{m}.

Toward West at 9^{h}00^{m} C.S.T.,
exposure 3^{m}.

PHOTOGRAPHS OF AURORAL STREAMERS, MARCH 22, 1920,
taken by Dean B. McLaughlin, Ann Arbor, Michigan.

PLATE XIV

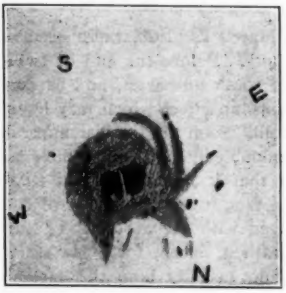
AURORAL STREAMERS PHOTOGRAPHED BY PROF. JOHN C. DUNCAN,
Whitin Observatory, Wellesley, Mass., March 22, 1920.

utes it was gone, although fragments of it seemed to linger for some time. The entire sky within 30° or so of the radiant turned violet and the whole horizon glowed with a still brighter green than before.

Although the display was still quite brilliant it had now passed the climax. By 9:30 the region of the radiant had become dark; only an occasional flicker appeared there. The color faded also and by 10:30 the greater part of the action was in the east and west with only a light tinge of green. At about 1:00 A.M., the activity had increased somewhat and the color had become more marked, but I did not observe it any longer.

During the display, I noticed the following curious facts. Before midnight, in the northwest quarter of the sky, streamers forming in the north drifted slowly toward the west; in the northeast quarter, try as I would, I could not determine any definite drift. After midnight, in the northeast quarter, there was a drift from north to east, but I could detect no drift in either direction in the northwest quarter. Does this indicate solar influence?

There was a great spot group on the sun at the time. Very fortunately, I had made a drawing of the leading spot that very noon. On the following day, I made another drawing. The spot was distinctly spiral in form and there was lit-



LEADING SUNSPOT, MARCH 22, $0^h\ 00^m$ (Noon) C.S.T.

LEADING SUNSPOT MARCH 23, $0^h\ 30^m$ P.M., C.S.T.

tle if any brightening at the inner edge of the penumbra. This was no optical effect, because the brightening was easily seen in the rear spot of the group. I was unable to distinguish the filaments of the penumbra, as I used a power of only 30 diameters. Today the seeing was better and I could distinguish the filaments in the penumbra of the rear spot but not in that of the leading spot. A new spot formed midway between them during the night of the display.

This was the first great aurora I had seen since 1916, when I watched the display of August 26. That display, however, was in no way equal to this and was almost totally lacking in color. The 1916 display was observed in central New York state.

Attempts to photograph the aurora were rather disappointing, but two photos show faintly, parts of the double arch. Some excellent star trails were secured incidentally. The failure of the photographs was due to the constant shift of the streamers and the negatives are uniformly dark all over.

A compass needle showed marked fluctuations during the display. These seemed to be mainly towards the west, although there is considerable doubt.

March 24, 1920. DEAN B. MCLAUGHLIN

CHESTERTOWN, MARYLAND.—An extremely brilliant display of Aurora Borealis occurred in the eastern section of the country on the evening of March 22, exhibiting all the phases of Aurora and covering an extremely large section of the sky.

The phases are as follows: March 22, 7:30 P. M.—White flashes as far south as Leo. 7:45—Aurora recedes to within 25° or 30° of pole. 9:10—Yellow glow 30° from pole. 9:18—Glow extends to Orion; white streamers like search-lights from east to west. 9:45—White streamers cease. Yellowish-green cloud as wide as the line from β Ursa Majoris to Regulus. Dusky cloud around horizon. 9:50—Green "curtains" of considerable depth in northwest, later crossing to north and ending in northeast. 9:55—Green "curtains" concentrate in northeast. 10:00—Red spot in east. Steady white streamers coming from all points on the horizon come to vertex around Regulus. 10:02—Purple spots play up and down these streamers. Red spot shifts to west. 10:05—Streamers turn greenish-yellow and purple, wave violently. 10:15—Streamers fade. 10:20 to 11:15—Flashings at intervals. 11:15—"Claw-like" streamers in southeast. 11:30—Aurora fades with intermittent flashes during the remainder of the night.

Some report hearing "rustling" or roaring as of distant thunder, but this is not positively certain. H. WILLARD CULP.

WELLESLEY, MASS.—On the evening of March 22, 1920, there occurred an auroral display of unusual brilliancy and beauty. Before the end of twilight a few filmy clouds were seen, especially in the south and west, and as darkness came on these clouds remained faintly luminous, an effect which may have been partly due to the Moon, which was two days old. Soon the familiar auroral arch appeared in the north, and other clouds, undoubtedly auroral in their nature, were seen in different parts of the sky, so that it became difficult to decide which were real clouds and which aurora. In fact, it seems to me probable that the clouds first seen were themselves connected with the aurora. The auroral arch was unusually high, and the region beneath it, except for a few occasional streamers, remained transparent, which has not usually been the case during aurorae seen here. The remainder of the sky, even down to the southern horizon, soon became filled with light. The aurora consisted partly of fairly quiescent, opaque clouds and partly of streamers, which latter were numerous and bright and changed with bewildering rapidity. These streamers often met to form a corona, which was brightest about 8^h E.S.T. and was visible at times until late in the night. It appeared always very nearly on the true meridian, at about 70° altitude, its position being unaffected by the diurnal motion of the celestial sphere. Another striking appearance that was seen more than once during the evening was a bright ray like the beam of a searchlight which traversed the sky from the west to the east point of the horizon, passing through the point occupied by the corona.

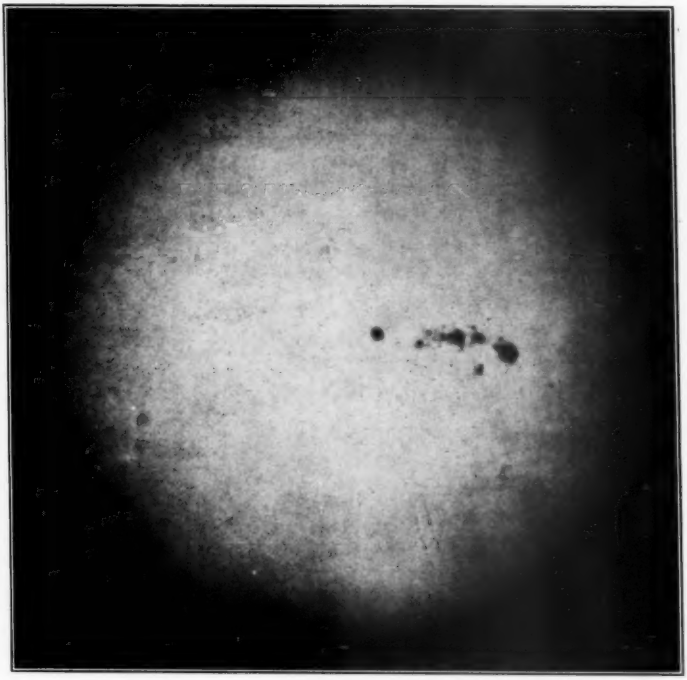
The color of this aurora was for the most part the usual pale green, though at times there appeared also a deeper green and the most beautiful shades of lavender and rose. Several times bright streamers were noticed which moved sidewise, and in each case the advancing side was tinged with red. Pulsations frequently passed from the horizon on all sides to the corona and upon arriving there flashed out momentarily with rose or lavender. A pocket spectroscope directed to any part of the sky except that beneath the northern arch showed the green aurora line and three faint lines or bands of greater refrangibility, but no red line was seen. At its brightest, about eight o'clock, the aurora gave

PLATE XV

AURORAL STREAMERS (EAST AND WEST) AT MIDNIGHT MARCH 24.

Looking southerly. Streaks are Mars (center) and Spica (right). Photographed by Wm. Henry, Brooklyn, N. Y.

PLATE XVI



GREAT SUNSPOT GROUP, MARCH 23, 1920.

Photographed by Wm. Henry, Brooklyn, N. Y.

enough light to enable one to read the time on an ordinary watch face. Faint aurorae were seen also on the nights of March 23 and 24. On the intervening days a large group of sunspots, easily visible without a telescope, were near the center of the solar disk.

The accompanying photograph was taken with a Bausch & Lomb "Tessar" lens, F 4.5, and an "Orthonon" plate. An exposure of 10^{s} was made for the crescent Moon, and the camera then closed and left undisturbed until after moonset, when a further exposure of 15^{m} was made on the same plate. The camera was directed due west from a point near the Whitin Observatory. The photograph shows the group of Wellesley College dormitories known as the Quadrangle silhouetted against the aurora-lighted sky and with some of their lights reflected in a temporary pond formed by recently melted snow. Several bright horizontal clouds and vertical streamers appear above the south towers, and a curved, nearly horizontal, streamer shows just above the Moon.

JOHN C. DUNCAN.

BROOKLYN, N. Y.—Probably the most brilliant display of Aurora Borealis ever seen around New York was witnessed by thousands here on the night of March 22.

Knowing that there was a very large group of sunspots near the meridian of the Sun, I kept a lookout for aurora, and about 7:45 first noticed the beautiful colors of an auroral curtain in the north. By 9:30 the streamers were very bright, shooting up towards the zenith like great searchlights at work.

About 10 o'clock there was an arch of light with a sharply defined dark outline on the bottom directly below Polaris, while great white streamers were radiating from a point in the northeast, while another set—equally brilliant—were shooting up from the northwest.

Knowing that the giant sunspot had a large spot at either end, while in between there was an immense network of small spots, I could almost visualize the connection of the whole auroral display with the shape of the sunspot group, with great streamers shooting up simultaneously from the northeast and northwest.

Great arches of yellowish green were shot through with straight streamers, gradually distorting and dissolving their formation, while the streamers met overhead in an everchanging bouquet of luminous clouds.

Then started a pulsating movement of the streamers, which, by this time, covered the whole sky, even down towards the southern horizon. These pulsations were very rapid—probably about five every second—and seemed to converge overhead. Bright patches shot up in all parts of the sky, disappearing suddenly like flashes of lightning. Every few minutes great draperies or curtains would form, only to be shot through with shafts of light, as if some painter were at work with a gigantic brush.

This display lasted until long after midnight, but seemed most brilliant between 9:30 and 11:30. Observation with a small spectroscope showed the green line very brilliant.

Reports showed that the phenomenon had been seen as far south as Charleston, S. C., and that telegraphic connection had been interrupted quite extensively.

Two nights later, on March 24, auroral streamers were very brilliant, only on this night they were confined to a section of the sky running from directly west to east along or near the ecliptic. WM. HENRY.

DELPHOS, OHIO.—Probably the most spectacular aurora of recent years occurred on the evening of March 22. Though perhaps lacking some of the intense color of the display of March 7, 1918, it more than equalled it in the variety of interesting forms which it assumed.

It was first seen at 6:50 P. M. though probably noticeable before this. Even as early as 7:00 P. M. many streamers from the north and northeast reached the zenith and the colors of red and green were quite prominent.

The maximum of the display occurred about 9:10 P. M. when it assumed the curtain form in the east. Replete with color and shaken with great rapidity, it was bright enough to cast a dark and well-defined shadow. The dark upright bands in the curtain moved always from east to west.

One of the most interesting features of the display was the convergence of the light rays and pulsations to a point in Leo which was twice estimated at:

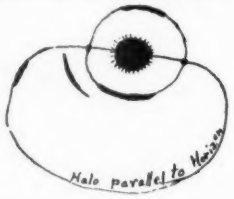
7:30 C.S.T. R.A. $9^h\ 50^m$ Decl. $+24°$
10:00 C.S.T. R.A. $10^h\ 12^m$ Decl. $+26°$

These positions are a little over a degree to the east of positions of the rays of the aurora of March 7, 1918. The pulsations were not present during the early evening and first became noticeable at about 9:00 P. M.

The display lasted throughout the night and was still present to some extent the following evening.

Of the large group of sunspots visible the following morning two could be distinctly seen with the naked eye. L. C. PELTIER.

A Peculiar Solar Halo.—At about 2:55 P. M., April 4, my attention was called to a peculiar and beautiful halo around the sun. This consisted of a circular halo around the sun, the radius of the circle being about 26°, the parts of the circle immediately above and below the sun being much brighter than the rest and rainbow hued. Southeast of the sun was the arc of another halo with a radius of 48 1/2° and which for a while showed the rainbow colors. This arc was about 15° in length. There was also another halo which was, so far as I was able to determine, parallel to the horizon at the sun's altitude, or in other words was on the same almucantar as the sun; and where this halo crossed the



other halo there was a bright sundog effect in colors, and this same phenomenon was also exhibited on the southeast part of this halo. The radius of this halo was 56 1/2° about the zenith as a center. These halos were light colored, except where mentioned, and were about one degree in width. I have never seen a halo parallel with the horizon before and I do not understand very well the cause of same. The rough sketch herewith shown may make it somewhat clearer. The horizontal halo lasted until about 3:35 and the other lasted for a while later.

Alma Center, Wis., April 5, 1920. DAVID A. BLENCOE.